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Critical Review of Smart City Concepts, Strategies and Indicators

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Master Thesis submitted in fulfillment of the Degree

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Submitted to PD Dr. Sabine Sedlacek

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AFFIDAVIT

I hereby affirm that this Master's Thesis represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed.

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ABSTRACT

This thesis examines the current state of knowledge regarding the smart city notion with a comprehensive literature review followed by the development of an own sustainable smart city concept. The latter serves as the basis for the assessment of three smart city concepts (London, Vienna and Zurich) relating to a set of indicators.

London's strategy is mainly focused on digitalization, and therefore can be labeled as a clearly technology-driven strategy. Vienna's smart city strategy is the most comprehensive one, and is also the strategy that takes up the latest and most complete definition of a smart city by accounting for the SDGs. Zurich's strategy outlines policy objectives in the broad fields of urban smartness, but is a rather thin strategy mainly focusing on already existing urban development concepts and plans.

The thesis shows that a smart city concept can only be meaningfully implemented if it takes into account the concept of sustainability as defined by the UN sustainable development goals.

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LIST OF ABBREVIATIONS

CAB Community Analysis Bureau (in Los Angeles)

EEC Emissions Embodied in Consumption

GDP Gross national product

GLA Greater London Authority

ICT Information and communication technologies

IT Information technology

ITS Intelligent Transport Systems

KPI Key performance indicators

LODA London Office for Data Analytics

LOTI London Office of Technology & Innovation

PPS Purchasing Power Standard

QoL Quality of Life

SCWFS Smart City Wien Framework Strategy 2019-2050

SLT Smarter London Together – The Mayor’s roadmap to transform London into the smarted city in the world

SME Small and mid-sized enterprises

SNA Social Network Analysis

SSCZ Strategy Smart City Zurich

SZ 2035 Strategies Zurich 2035 Zurich

TfL Transport for London

1 INTRODUCTION

1.1 Context and background

In the context of the rapidly increasing population in urban agglomerations, climate change, socio-demographic changes, scarcity of resources, growing inequalities, governance and participation requirements and strong technological innovations, there has been a notably growing academic and practical attention towards the smart city idea within the last several years. Although the smart city concept is still evolving, it can be hypothesized that smart city concepts that are not technology-centric but sustainability-focused are still strongly underrepresented. Focusing on the benefits of using urban technology promises efficiencies that are expected to mitigate rising environmental concerns and associated resource scarcity. However, this suggests that the planning of smart city measures does not fully consider sustainable planning as laid out e.g., by the UN New Urban Agenda in correspondence with the 2030 Agenda for Sustainable Development. In this context, particular reference is made to Goal 11 of the 2030 Agenda for Sustainable Development on sustainable cities and communities referring to "making cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2017, p. 4). A large number of concepts, definitions and buzzwords can be found in the scientific literature. Moreover, there is still no generally scientifically accepted definition of a smart city concept. This makes the design of urban policy but also the planning and implementation of smart city initiatives as well as their comparability and measurability considerably more difficult.

Against this background, the present thesis therefore poses the **question** of *how smart city concepts based on technology and/or governance and/or sustainability approaches can be evaluated by means of three selected European cities*. The selected cities are London, Vienna and Zurich.

In reference to this overall research question of this thesis, the following more detailed questions will guide the research:

- Which smart city concepts exist and how do technology driven concepts differ from socio-economic and governance concepts?
- Which evaluation and indicator systems for smart city concepts are established?
- What are the strengths and weaknesses of smart city concepts in three selected European cities?

The thesis is structured as follows. First, a literature review presents current smart city definitions as well as smart city concepts and the most relevant smart city rankings, which in turn form the basis for smart city concepts. Based on an own operational definition of the smart city concept, the methodology of evaluating smart city concepts is elaborated. Section 4 then presents the evaluation of the three selected smart city concepts based on a set of indicators followed by the discussion of the results and the conclusions.

2 LITERATURE REVIEW

The following chapters present a theoretical introduction to the origins of the smart city notion and a broad literature review on the different smart city concepts and definitions. To date, there is no universally valid and generally accepted definition of the smart city idea. The various concepts being described in the subsequent sections each represent different viewpoints and aspects from various disciplinary and policy-relevant angles.

2.1 The origin and emergence of smart city concepts

While most of the literature sources aim at a period of origin for the concept of a smart city between the 1990s and 2000s by arguing that the smart city phenomenon emerged with the technological advancement especially within the IT-sector (e.g., Dameri et al., 2018, Caragliu et al., 2009), Cugurullo (2018) goes to the bottom of the matter in a more thorough manner.

According to the author (Cugurullo, 2018) no single definition of the smart city concept exists. Nevertheless, the existence and the use of technology as well as technological innovation is a commonality in all concepts and definitions of a smart city, respectively. Based on this understanding, Cugurullo (2018) refers to Francis Bacon's work, "Novum Organum Scientiarum" (the new instrument of sciences) of 1620, in which – presumably for the first time – science in close connection to technology is declared as the instrument of choice to subjugate nature to human needs. Francis Bacon's "New Atlantis" (first published in 1627) is a utopia describing, inter alia, the island of Bensalem, a large laboratory where the participants engage in infinite technological innovation. The residents of Bensalem create futuristic means of transport (e.g., submarines), flying instruments and robots. By this, Bacon was presumably the first to establish a link between modern technology and urban planning. The author further states that two central innovations influence the urban technological development in a substantial way: The Second Industrial Revolution and the modern development of ICT (information and communication technologies).

The Second Industrial Revolution was characterized by the invention of steel, its application, inter alia, in reinforced concrete allowing the development of high-rise buildings and shortly thereafter, the invention of the automobile with the subsequent emergence of highways that significantly changed urban structures.

The rise of ICT ("ICT revolution", Cugurullo, 2018, p. 8) was the second peak in technological advancement with significant urban planning consequences. Both developments (the Second Industrial Revolution and the development of ICT) were accompanied strongly by the capitalist way of production and promoted by large private companies. Nevertheless, from a visual point of view, the rise of ICT was not as material as the upcoming of industrial products like steel, concrete, engines, and automobiles. Despite being connected to a physical infrastructure, ICT has an "ethereal essence" (p. 8), and the hardware devices follow the "logic of miniaturization in order to occupy less physical space" (p. 8 f). The first practical example of a pioneering city for smart urbanism is Los Angeles, which was the first city that shaped its urban development on the basis of vast amounts of data on traffic, housing, crime and poverty already in the 1970s. The goal of this undertaking was to provide information to planners and policy makers (Cugurullo, 2018).

Therefore, Los Angeles is mentioned as the first particular case of a "computer city" (Cugurullo, 2018). According to Valliantos (2015), Los Angeles founded the Community Analysis Bureau (CAB) with the aim of providing data to be used for the development of policies to combat poverty and social injustice. The goal was to identify the residential areas with a deteriorating building fabric. Consequently, the CAB developed a variety of analytic and technological procedures to assess the quality of housing. For instance, a cluster analysis showed the residential areas of similar social and physical characteristics. Key data at that time were population, ethnicity, education, housing, crime rates, and an environmental quality rating. Additional to the IT-based analysis, the CAB took aerial photographs of one million houses spread over 500 square miles between 1971 and 1978 and subsequently rated each photo print. As a consequence, the "first 'State of the City' report explained, 'It has become obvious that the traditional approach to urban renewal, the treatment only of physical problems, is not adequate […] to deal with the social, economic, and physical nature of urban decay.' Recommendations from that report included raising family incomes above poverty level, placing all needy three-to-four-year-olds into preschool, and spurring the construction of 7,000 to 9,000 low-to-moderate income housing units per year, in addition to those already planned" (Vallianatos, 2015).

In contrast to this perspective, Yigitcanlar et al. (2019b) consider the smart city notion as a by-product of the "smart growth movement of the 1990s" (p. 349) by referencing Downs (2005).

According to Downs (2005), the smart growth movement is a reaction and a tool, respectively, for urban planners to counteract urban sprawl (strong outward expansion on formerly agricultural land with low density) and other undesired (negative) externalities, such as land rezoning from environmentally valuable land towards urban use, problems caused by motorized private transport (e.g., traffic congestion, pollution, land consumption and land sealing), high financial requirements due to the expansion of municipal infrastructure (e.g., roads and public utilities) caused by urban sprawl, deficits in redevelopments and urban densification, as well as segregated land use instead of a mixed one. In regard to urban development, Smart Growth has therefore been guided by the following principles (compare Downs, 2005).

- Limitation of the urban sprawl and the consumption and sealing of land by defining, e.g., urban boundaries; intensification of the densification of land in development areas as well as in given neighborhoods (including revitalizing existing neighborhoods)
- Creating incentives for pedestrian traffic to reduce motorized private transport and increasing mixed zoning areas

- Passing on the costs of the expansion of urban infrastructure to developers (instead of the public sector bearing these costs)
- Prioritizing public transport over motorized private transport
- Promotion of affordable housing
- Reducing obstacles for developers
- Diverse regulations with regards to aesthetics, design, public spaces and street layouts

From the author's viewpoint, the last two arguments of Downs (2005) may be in direct contradiction to the first five aspects. The liberalization of urban development in order to involve private investors and real estate developers, or to extend public-private partnerships, can hinder social housing policies, increase public infrastructure costs and pose threats to the urban densification objectives. Secondly, loose zoning regulations may as well support urban sprawl. Thirdly, a recent review of public-private partnerships (PPPs) in European infrastructure policies has discovered that PPPs almost always are disadvantageous for the public sectors and citizens (tax payers) alike (Lethbridge and Gallop, 2020).

Other scholars (e.g., Cocchia, 2014; Riesenecker-Caba, 2016; Yigitcanlar et al., 2019b) date the beginning of the smart city idea and the rise of its popularity, respectively, to a – clearly industry-driven – speech by Samuel J. Palmisano (then IBM Chairman, President and CEO) in November 2008 on "A Smarter Planet: The Next Leadership Agenda". This speech addressed mainly ICT-based leveraging of the potentials of increasing efficiency in broad policy fields such as waste management, reduction of pollution, modernization of health care systems, potable water management, and financial risk management (IBM, 2008).

This short list of examples infers that the smart city notion and the idea of using technologies – in a utopian or a practical policy-oriented way – in urban planning and policies have developed over a long period of time. However, while many definitions of smart cities still rely heavily on a technological perspective, the understanding of smart cities has been significantly complemented by a wide array of additional elements originating, e.g., in social and political sciences. Thus, we now turn to the presentation of more recent concepts of smart cities.

2.2 Definitions and concepts of "smart city"

2.2.1 The fuzziness of definitions of "smart cities"

When reviewing the scientific literature referring to smart cities and searching for a definition of (the) smart city concept(s), it quickly becomes apparent that there is no definition of the term "smart city" that is both comprehensive, and broadly accepted by the scientific community or by related institutions at the same time. There is neither a common understanding of the relevant elements of a smart city, nor of its boundaries or limitations (Cocchia, 2014). Therefore, the smart city concept is often labeled as "fuzzy" (e. g. Caragliu et al., 2009, Dameri et al., 2019, Lara et al., 2016) or "ambiguous" (e.g., Vanolo, 2014, Letaifa, 2015).

According to Cocchia (2014), the reasons behind this ambiguity are due to two distinct aspects:

(1) "Smart" as an adjective has a broad meaning and can be interpreted in very different ways. The scientific literature refers to several smart city concepts and their offshoots or predecessors such as, among other labels, "Intelligent City, Knowledge City, Wired City, Digital City" (Cocchia, 2014, p. 18).
(2) Due to the fuzziness of the various concepts oftentimes not being in accordance with each other, numerous cities see themselves as a Smart City by labeling (or marketing) their policies as "smart" without referencing to a broadly accepted and standardized meaning.

Nevertheless, the scientific literature offers numerous definitions and attaches clear attributes to the phenomenon of a "smart city" with reference to the corresponding alignment of the definition and its scientific focus. The following sections summarize the most prominent definitions and concepts.

2.2.2 The difference between "traditional" and "smart" cities

Lom and Pribyl (2020) conceptualize the differences between "traditional cities" and "smart cities" on the basis of systems theory by quoting D. Rousseau (2015). Accordingly, systems are a "set of interacting or interdependent component parts forming a complex whole. Every system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning". Lom and Pribyl (2020, p. 2) state: "A system can be divided into subsystems. A subsystem is a separable and identifiable part (component, element) of a system." Consequently, the term "city" can be defined under this notion as "a large and permanent human settlement" […] consisting "of complex subsystems for example for sanitation, utilities, land usage, housing, or transportation" (James et al., 2013, quoted in Lom and Pribyl, 2020, p. 2).

In this conceptual framework (Lom and Pribyl, 2020), "traditional cities" with their associated subsystems are regarded as independent systems not being able to communicate with their own immediate environments. In contrast, "smart cities" are characterized by urban systems and subsystems interacting and exchanging information with other systems and subsystems, respectively. For instance, the transport (sub-) systems may communicate and exchange data or information with an energy provider or a smart grid (Lom and Pribyl, 2020). Consequently, the concept of a "smart city" may at least include a technological perspective (see section 2.1) and an integrative approach that accounts for the interlinkages of urban systems and subsystems.

Another definition of the term "city" is given by Dizdaroglu and Yigitcanlar (2014, p. 115)[1] by stating that a city would be "the most dramatic manifestation of human activities on the environment […]. This human-dominated organism degrades natural habitats, simplifies species composition, disrupts hydrological systems, and modifies energy flow and nutrient cycling […]. To examine this interaction, we need to consider cities as 'urban ecosystems', in other words, […] 'urban ecological spaces', with their biological and physical complexities that interact with each other. Urban ecosystem is a dynamic organism that comprises of natural, built and socio-economic environments". This concept of a city according to Dizdaroglu and Yigitcanlar (2014) can be considered as very useful for the smart city debate since it points to the physical fundamentals of life in cities. As discussed in this thesis, smart cities in a broad definition have to reduce resource use, cap greenhouse gas emissions, and promote a sustainable (urban) development among other goals (see for more details and the author's viewpoint on smart cities, section 2.6).

2.2.3 A human-centered and context-free approach

Lara et al. (2016) argue that the currently available definitions of smart city concepts "have limited scope" by being too strategy- and action-centered instead of linking the smart city concept with the "creation of environments that promote happiness and wellbeing of their residents" (p 2). The authors therefore offer a definition for the concept of smart cities with the explicit aim of being "comprehensive, human-centered, and context-free" (p. 2): Therefore, a smart city "is a community that systematically promotes the overall wellbeing for all of its members, and flexible enough to proactively and sustainably become an increasingly better place to live, work and play" (p. 6). This definition is clearly human-centered, nevertheless it also includes - although not explicitly mentioned - relevant components such as technological and institutional factors, which are the three fundamental components laid out by Nam and Pardo (2011).

While this understanding of smart cities offers a theoretical and methodological framework in relation to investigating the connections between urban technologies, the urban residents, and their wellbeing, it is also highly normative in the sense of prescribing a smart urban development as sustainably promoting the well-being of the citizens. The first positive/analytical perspective offers indicator systems (e.g., the "Smart City Wheel" (see chapter 2.3.2) or the components of a smart city presented in the sections below). The latter normative/prescriptive perspective defines the smartness in terms of qualitative indicators, and the achievement of certain policy goals.

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[1] Dizdaroglu and Yigitcanlar (2014) refer in their definition of "city" to four further literature sources (Ridd (1995); Alberti (1996), Yigitcanlar (2010) and Alberti (1996)).

2.2.4 A technology-centered approach

As already mentioned in Chapter 2.1, IBM was one of the first stakeholders contributing to the smart city notion. IBM's understanding of the smart city concept is purely technology-driven with the claim to make urban infrastructure systems more efficient. According to IBM Global Business Services (2009, p. 9f.), smart and "smarter cities", respectively,

- "know how to transform their systems and optimize the use of largely finite resources" (p. 9)
- "make their systems instrumented, interconnected and intelligent" (p. 10)
- "transform their systems and their 'system of systems'"[2] by applying technology to transform a city's "core systems and optimize the return from largely finite resources" (p. 10).

Furthermore, connecting a city's systems will lead to increased efficiency, and will therefore contribute to sustainability. Due to a city's limited resources, the evolution toward the smartness of a city should be viewed as a "journey" rather than an "overnight transformation" (p. 10).

Increasing efficiency of resource use is certainly necessary and also part of the UN sustainable development goals, but nevertheless not sufficient per se to reduce total resource consumption (see for further discussion also sections 2.4 and 2.5).

According to Hill (2010), the following fields of applications depicted in Table 1 may arise for IBM's technology.

[2] IBM Global Business Services (2009) consider a city as a collection of numerous "core systems" (p. 10), which in turn add up to the "system of systems" (p. 10).

TABLE 1: SUGGESTED FIELDS OF APPLICATIONS FOR ICT TECHNOLOGY WITHIN SMART CITY CONCEPTS

Intelligent Transportation Systems	Road usage charging/congestion pricing Integrated fare management Traffic information management
Energy Management	Smarter building management Automated meter management Smart Grid – demand management Energy network monitoring & stability Proactive management of the alternative energy mix
Environmental Management	City-wide measurements Key performance indicators (KPI) Energy, water, waste, CO2 management Scorecards Reporting
Water Management	Water purity monitoring Water use optimization Waste water treatment optimization
Public Safety	Smarter surveillance systems Emergency management integration Micro-weather forecasting Cyber-security
Telecommunications	Fixed and mobile operators - media broadcasters

Source: Hill (2010, p. 6), author's draft.

Since IBM's approach laid out above is purely technology-centric, it should be noted here that this view also has its critics (see also chapter 2.4). Especially the notion of improved efficiency and the contribution of ICT towards improving urban sustainability bears the danger of rebound effects on the side of consumers (citizens) due to income and pricing effects. Rebound effects imply that savings due to the (technical) improvements of efficiency, caused by corresponding investments, lead to increased consumption or to a higher quality of a service. Rebound effects are known to appear, e.g., in the automotive industry, where the use of lighter materials, more efficient engines or improved aerodynamics have led to the purchase of larger and less efficient cars (Giffinger, 2016; Herring and Roy, 2007).

Besides that, lock-in effects (technological, economic, legal, institutional) where stakeholders are dependent on a certain supplier (e.g., a certain type of fuel for heating) and cannot switch to a different company without bearing high costs or substantial inconveniences might occur as well. Lock-in effects become even more severe as initial investment costs for certain technologies are high and lead to municipal public debt (Giffinger, 2016; Unruh, 2002; Seto et al., 2016).

Another approach that is also rather technology-centered is shared by the European Commission (2021a), although it is explicitly noted that there is more to smart cities than solely applying ICT. Nevertheless, the main purpose of smart cities according to the European Commission is the more efficient use of resources.

"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, 2021a).

In the author's view, the definition given above does not fully match the European Commission's own SMART initiative (see Borsboom-van Beurden et al., 2019; more details are provided in chapter 3.3), as the understanding of smart cities within this initiative is much broader and aligned with the UN Sustainable Development Goals (see also chapter 2.4).

2.2.5 Multidimensional approaches towards defining a smart city

Nam and Pardo's (2011) definition of the smart city concept, derived from the intersection of the three "fundamental components of Smart City" – technology factors, human factors and institutional factors (Figure 1) –, is based on their analysis and consolidation of the elements and dimensions of a wide range of smart city concepts (p. 286). From the authors' viewpoint, the smart city concept is located in the overlapping areas of numerous urban development and urban policy concepts (see also Table 2 below that presents some of the concepts mentioned in Figure 1).

Like other authors (e.g., Dameri et al., 2019), Nam and Pardo (2011) stress the combination of technological, human and institutional factors as constitutional for a smart urban development. This combination and integration of different realms is based on the understanding that technological progress and the implementation of ICT is not sufficient for a smart (sustainable) urban development. While the technological factors have been labeled as "digital" or "wired" city concepts, sustainable policies have to be implemented by governance institutions, and have to be accepted by citizens. Therefore, enabling technologies to fulfill their aims of, e.g., reducing urban pollution, curbing greenhouse gas emissions, or increasing the efficiency of the public transport system, requires smart governance (i.e., implementing appropriate frameworks for new technologies) and the appreciation of the citizens. The Figure 1 below shows the model components according to Nam and Pardo (2011), although one could argue that a relevant factor – the physical environment and urban structure is not included.

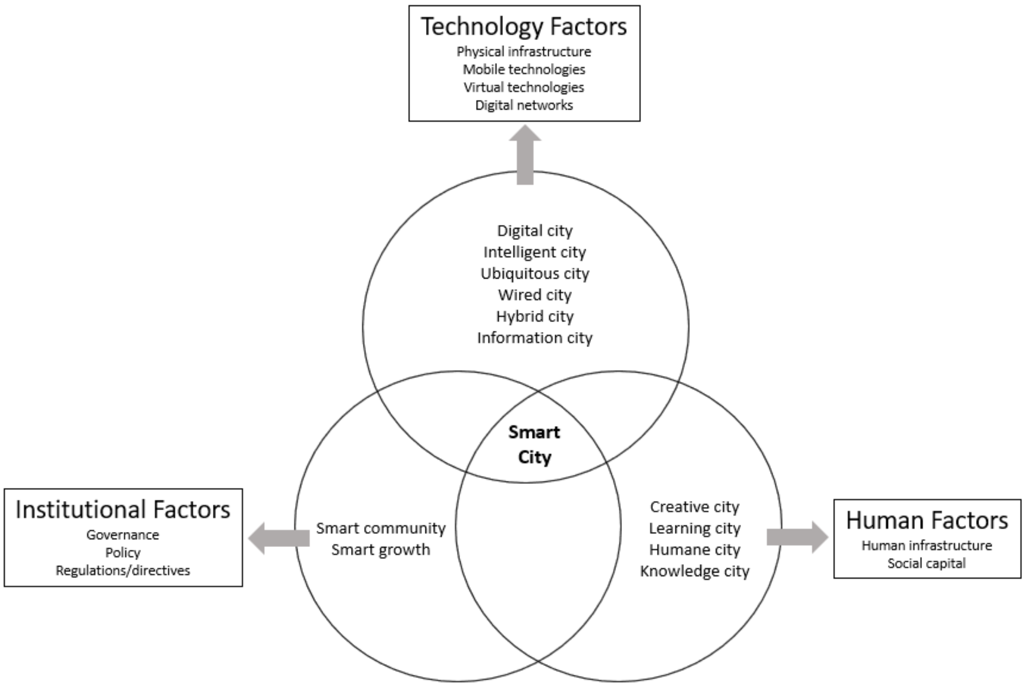


Figure 1: Fundamental Components of a Smart City

Source: Nam and Pardo (2011), author's draft.

The authors stress the importance of technologies as well as their availability and accessibility that are a prerequisite of the application of ICT. A reference is made to Washburn's et al. (2010, p. 2) definition of a central elements of the smart city concept:

"The use of Smart Computing technologies to make the critical infrastructure components and services of a city — which include city administration, education, healthcare, public safety, real estate, transportation, and utilities — more intelligent, interconnected, and efficient". Smart Computing is further defined as: "A new generation of integrated hardware, software, and network technologies that provide IT systems with real-time awareness of the real world and advanced analytics to help people make more intelligent decisions about alternatives and actions that will optimize business processes and business balance sheet results." The required components of Smart Computing according to Anthopoulos and Fitsilis (2009, p. 1 f) are: network equipment (e.g., fiber optic channels, wi-fi networks in the city area), service-oriented information systems (e.g., eGovernment and eDemocracy portals), public access points (e.g., wireless hotspots, info kiosks), and social service systems (e.g., intelligent transport systems). However, technologies are not understood as a mere stock of technical equipment, but considered and discussed in their potential roles for innovations. Technological infrastructure systems therefore serve as a basis in the sense of using it as a "means", not an "ends", for enhancing the innovative capacity of a city.

The technological factors according to Figure 1 aim at enabling and fostering a creative and innovation-oriented environment allowing the formation of a city's human capital, but are themselves dependent on education, participation and social learning (social capital[3]). Therefore, the human factors of a smart city concept are aimed at the citizens and their ability to learn, innovate and build up social capital. As a consequence, public (urban) services are to be made accessible to all citizens by reducing or eliminating barriers related to language, culture, education, skills and disabilities. The third aspect – the institutional factor – covers the engagement and participation of citizens, and the collaboration, cooperation and partnerships among different groups of stakeholders (e.g., businesses, academics, non-profit organizations/civil society), local/regional governments, and different jurisdictions. City governments may be required to share relevant information, concepts, goals and priorities with the public respectively with all stakeholders interested in urban development (Nam and Pardo, 2011).

This understanding of the different factors highlights the importance of a dynamic perspective on smart cities. The "smartness" of a city is not a certain state at a certain point in time, but is the ability of a city to develop in a smart way, taking all dimensions – technological, institutional, human – into account.

Cocchia (2014) conducted an extensive literature review on smart and digital city concepts. At the core of this author's concept, an approach similar to the one by Nam and Pardo (2011) is discussed. Cocchia (2014) argues that smart city concepts are practically always based on ICT infrastructure as a prerequisite for smart urban development. The concept of "smart" is therefore closely related to "digital", which is stressed by numerous concepts in the scientific literature by stating that the concept of the "Digital City" uses the "most recurrent terminology linked to the meaning of Smart City" (p. 18). The concept of the digital city is seen as a subset of the smart city, similar to the conceptual model of Figure 1. The definitions of the digital city concepts, however, show greater uniformity due to their focus on ICT than those of a smart city which is much broader in terms of the different factors and dimensions included.

The above-mentioned attributes towards smart and digital cities are derived from a broad range of different concepts of development paths of cities, based on a comprehensive overview of

[3] There are, of course, various concepts and meanings of "social capital". Claridge (2019) provides an updated overview of definitions. In most general terms, social capital may be defined as the quantity and quality of social networks and relations in connection with trust, reciprocity, and common values/beliefs/attitudes. Social capital facilitates communication, innovativity, social learning, and generally provides a broad range of benefits for citizens being part of the social fabric (source: own concept and summary based on Claridge, 2019). Atshan et al. (2020) emphasize the "benefits of social capital" as "social ties by means of resources available through those ties" by referencing Putnam (1993) and Thoyre (2011).

literature sources. Cocchia (2014, p. 19f) provides the following definitions, each based on a specific literature source (see Table 2 below).

TABLE 2: OVERVIEW OF DIFFERENT CONCEPTS RELATED TO SMART CITIES AND SUSTAINABLE DEVELOPMENT

City Concept	*Definition*
Wired city	Wired cities refer literally to the laying down of cable and connectivity not itself necessary smart.
Virtual city	Virtual City concentrates on digital representations and manifestations of cities.
Ubiquitous city	Ubiquitous city (U-City) is a further extension of digital city concept. This definition evolved to the ubiquitous city: a city or region with ubiquitous information technology.
Intelligent city	Intelligent cities are territories with high capability for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management.
Information city	Digital environments collecting official and unofficial information from local communities and delivering it to the public via web portals are called information cities.
Digital city	The digital city is a comprehensive, web-based representation, or reproduction, of several aspects or functions of a specific real city, open to non-experts. The digital city has several dimensions: social, cultural, political, ideological, and also theoretical.
Smart community [a]	A geographical area ranging in size from neighborhood to a multi-county region whose residents, organizations, and governing institutions are using information technology to transform their region in significant ways. Co-operation among government, industry, educators, and the citizenry, instead of individual groups acting in isolation, is preferred.
Knowledge city	A Knowledge City is a city that aims at a knowledge-based development, by encouraging the continuous creation, sharing, evaluation, renewal and update of knowledge. This can be achieved through the continuous interaction between its citizens themselves and at the same time between them and other cities' citizens. The citizens' knowledge-sharing culture as well as the city's appropriate design, IT networks and infrastructures support these interactions.
Learning city	The term 'learning' in 'learning cities' covers both individual and institutional learning. Individual learning refers to the acquisition of knowledge, skills and understanding by individual people, whether formally or informally. It often refers to lifelong learning, not just initial schooling and training. By learning, individuals gain through improved wages and employment opportunities, while society benefits by having a more flexible and technological up-to-date workforce.
Sustainable city	Sustainable city uses technology to reduce $C0_2$ emissions, to produce efficient energy, to improve the buildings efficiency. Its main aim is to become a green city.
Green city	Green City follows the Green Growth which is a new paradigm that promotes economic development while reducing greenhouse gas emissions and pollution, minimizing waste and inefficient use of natural resources and maintaining biodiversity.

[a] California Institute (2001), cited in: Cocchia, 2014.

Source: Literature review by Cocchia (2014, p. 19 f.) based on Hollands (2008), Schuler (2002), Anthopoulus et al. (2010), Couclelis (2004), Ergazakis (2004), Larsen (1999), Batagan (2011) and OECD (2010); adapted by the author.

In addition to the model of the three factors of smart cities by Nam and Pando (2011) presented above in Figure 1, the overview of the related concepts of Cocchia (2014) includes the "sustainable" and "green" city as important definitions in the context of smart cities. Both concepts place their emphasis on the efficient use of resources (e.g., energy) and on mitigating and adapting to climate change. However, the "green" city also contains the idea of the feasibility of "green growth" – a notion, that has been challenged by the (physical) limits to growth, and the empirically robust positive correlation between economic growth and the quantity of natural resources used for production and consumption (compare in a global perspective, e.g., Steinberger et al., 2013).

2.2.6 The inclusion of the territorial factor

Dameri et al. (2019) offer an expanded explanation of the smart city concept by adding the territorial component ("land") as a fourth attribute besides the various factors conceptualized in the model by Nam and Pardo (2011) above-mentioned. Dameri et al. (2019) emphasize the central role of the territorial component[4] as a key factor in defining the smart city concept due to its environmental aspects (e.g., pollution, available resources), geographical aspects (referring to the political as well as the physical geography), and cultural heritage (including the territory's history).

It was noted above that the dynamic nature of the smart city in regard to urban development is a core characteristic of "modern" smart city concepts. However, the perspective of time may also relate to past decisions especially on urban structures and land use, and infrastructures (e.g., energy). Smart urban development may often be hindered by the economic, technical, institutional or behavioral lock-in effects (Unruh, 2002; Seto et al., 2016).

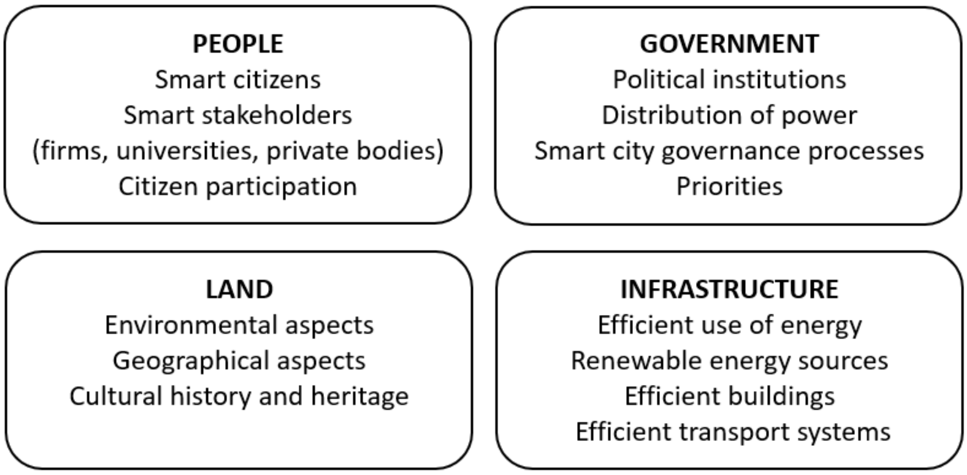


Figure 2: Dameri's smart city model including the territorial aspect

Source: Adapted from Dameri et al. (2019, p. 28), author's draft.

[4] It is somewhat surprising that smart city concepts need to mention the territorial aspect of urban planning as a distinctive characteristic. It should be completely clear that the "territorial factor plays an essential role in all urban development models" (Sedlacek, 2021).

Summarizing various concepts and providing her own assessment, Dameri (2013) defines a smart city as follows[5]. A smart city is a well-defined geographical area where high technologies, such as ICT, logistics, and energy production, work together to create benefits for citizens in terms of well-being, inclusion and participation, environmental quality and smart development. It is governed by a well-defined pool of people who are able to set the rules and policies for urban management and development. This definition accounts for the technical (infrastructure) perspective, the governance and people's perspective, and the scarcity of resources and the environmental aims of smart development in cities. However, this understanding of smart cities is still rather vague in regard to the causes of environmental degradation, especially to the role of the urban transport system (urban mobility) in determining local and regional pollution, and, in general, the design of the public space and the extent to which it is devoted to smart mobility.

2.2.7 Smart city in the context of smart mobility

An approach focusing on one specific aspect of the smart city concept is laid out by Papa et al. (2017). According to the authors, "a city is smart when [it] is able to respond to the needs of its inhabitants in a more efficient and sustainable way, mainly by properly using information and communication technologies (ICTs)" (p. 409). Papa et al. (2017) clearly integrate the technological and the "human" (people's, residents') perspectives as equally important in their understanding of smart cities.

In the light of the other explanations of smart city concepts available in the literature discussed above, however, this approach seems to be rather limited in focusing specifically on smart mobility, or, in the words of the authors, on "Intelligent Transport Systems (ITS)", respectively. ITS are defined as systems, which "reduce pollution and congestion, increase safety and improve the management and promotion of public transport demand" (Papa et al., 2017, p. 409).

Within the general framework of "smart mobility", the authors differentiate further (by referencing Staricco, 2013) between "smart mobility as a mobility that is efficient and effective, regardless of the use of ICTs", and mobility that aims at "the key role of new technologies" (p. 409). Given the need of ICT, Papa et al. (2017) emphasize the indispensability of smart mobility not solely being a technological matter, but also "a social and cultural approach" (p. 410). From this viewpoint, a smart city does not only deal with "smart transport" in the sense of reducing

[5] The original text was adapted to correct spelling and grammar errors. Therefore, the author does not use quotation marks despite close similarities with the original text which is as follows: "A smart city is a well defined geographical area, in which high technologies such as ICT, logistic, energy production, and so on, cooperate to create benefits for citizens in terms of well being, inclusion and participation, environmental quality, intelligent development; it is governed by a well defined pool of subjects able to state the rules and policy for the city government and development" (Dameri, 2013, p. 2549).

emissions and implementing ICTs in the transport system. A smart city also accounts for the behavioral circumstances, i.e., how citizens choose their mode of transport, and which socio-economic and cultural factors determine this choice ("smart mobility").

2.3 Smart city concepts for smart city rankings

With the emergence of hundreds of smart city concepts around the globe in recent years, and the increasing globalization, rapid technological innovation, and growing competition to attract companies and corporate headquarters, scientific research and development facilities, the need for benchmarking and ranking cities is emerging. Urban policy makers and planners seek policy relevant guidance and recommendations for sustainable urban planning and for the preparedness for future challenges towards enhancing the resilience of cities against exogenous shocks such as climate change, pandemics, or shortages of resources. Of course, the underlying smart city concepts also form the foundations for the respective frameworks for rankings, benchmarking and evaluations. The following sections present selected ranking schemes for smart cities which will again be referred to in section 3.4 for the design of the empirical assessment of smart city concepts.

2.3.1 Ranking Scheme used for European mid-sized cities according to Giffinger et al.

Giffinger et al. (2007) give a comprehensive, elaborated and reliable definition of the smart city concept. Their approach serves as the basis for smart city rankings that require a transparent and well-defined assessment structure. The authors intended to base their ranking on the broadest contents possible. This approach ensures that not only the performance of one aspect (indicator) is taken into account, but that a wide range of characteristics of a city to be assessed in regard to its smart development is used. The characteristics are meant to be based on a "forward-looking development" (Giffinger et al., 2007, p. 10) influenced by the existing local conditions, and the actions and decisions made by citizens, local politicians and private businesses.

A "forward-looking development" (p. 10) refers to the various attributes of urban systems and urban development, such as awareness, flexibility, transformability, synergy, individuality, self-decisiveness, and strategic behavior. Great importance is attributed to the awareness of all stakeholders in regard to smart urban development, since a city can only realize its full potential by the cooperation and the special attention of all stakeholders with tacit knowledge, and who know the city and its surroundings from various points of views.

Giffinger's et al. (2007) approach intends to be holistic as well as is based on a thorough scientific understanding. Therefore, the aim is to combine various approaches towards smartness (smart urban development). As some scholars apply the term "smart" in various contexts, such as "smart industry", smart (well-educated) inhabitants, or smart governance in the sense of communicating with the citizens via e-portals, the authors came up with several subject (policy) fields. These are “industry, education, participation, technical infrastructure […]” and “various ‘soft factors’” (p. 10).

Based on the considerations discussed above, Giffinger et al. (2007) provide the following definition. “A Smart City is a city well performing in a forward-looking way in these six characteristics, built on the ‘smart’ combination of endowments and activities of self-decisive, independent and aware citizens” (p. 11). The characteristics (dimensions, policy fields) are: Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living as laid out in Figure 3 below (the figure does not infer a hierarchical relation between the six fields of smart urban development).

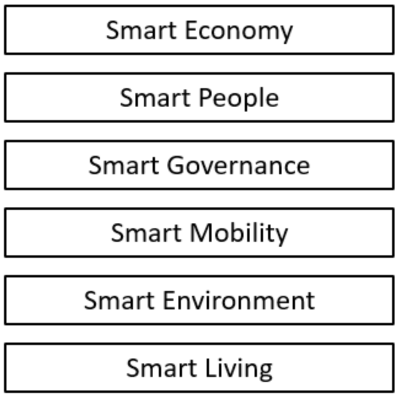


FIGURE 3: CHARACTERISTICS OF A SMART CITY AND SMART URBAN DEVELOPMENT
Source: Giffinger et al. (2007), author’s draft.

Based on the six characteristics of a smart city listed above, a hierarchy of factors and indicators is developed. As a result, the six characteristics are formed by a series of 33[6] factors, which consist of numerous empirical (operational) indicators (74 in total). The authors therefore provide a distinct and consistent system of empirical indicators in order to assess the smartness of cities and their urban development – an approach that clearly distinguishes their research strategy from that of other authors. In addition, this definition of a smart city accounts for the dynamic (evolving) perspective of cities; “smart” is therefore not considered a certain state (point in time), but as a development path that includes urban resilience (see Davoudi, 2012) and the capacities of urban policy-makers, planners and stakeholders to tackle and design innovative solutions for urban problems, such as the mitigation and adaption to climate change.

[6] Although 33 factors were identified, only 31 factors were included in the empirical analysis and the ranking (assessment) of smart cities. The factors “ability to transform” and “political strategies and perspectives” were excluded due to a lack of data (Giffinger et al., 2007).

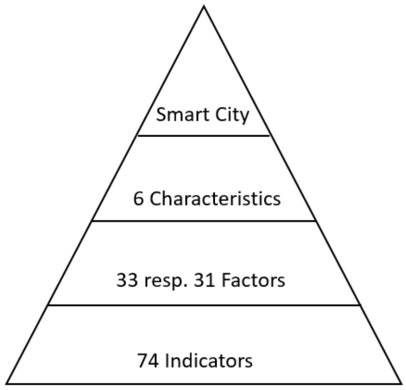


FIGURE 4: STRUCTURE OF CHARACTERISTICS, FACTORS AND INDICATORS

Source: Giffinger et al. (2007), author's draft.

Table 3 below includes the six characteristics of smart cities and their corresponding factors. The "Smart Economy" refers to competitiveness comprising innovation, entrepreneurship, trademarks and productivity as well as labor market flexibility and international economic relations. "Smart Governance" includes a well-functioning public administration, the provision of public services and the possibilities for participation. "Smart Environment" includes the attributes of a healthy environment such as environmental protection, dealing with pollution, attractive natural conditions, and resource management, respectively. "Smart People" is not only aiming at well-educated citizens, but also at a society's openness towards participation and inclusion. Accessibility (locally and internationally) are key factors of "Smart Mobility" including the availability of ICT infrastructure as well as sustainable transport systems. The final characteristic - "Smart Living" – contains all aspects around the "quality of life" such as culture, health infrastructure, safety aspects, housing, education, touristic attractiveness and social cohesion.

Table 3: Characteristics and factors of a smart city

Smart Economy (Competitiveness)	**Smart People (Social and Human Capital)**
• Innovative spirit • Entrepreneurship • Economic image & trademarks • Productivity • Flexibility of labor market • International embeddedness • *Ability to transform*[a]	• Level of qualification • Affinity to lifelong learning • Social and ethnic plurality • Flexibility • Creativity • Cosmopolitanism/Open-mindedness • Participation in public life

Smart Governance (Participation)	**Smart Mobility (Transport and ICT)**
• Participation in decision-making • Public and social services • Transparent governance • *Political strategies & perspectives*[a]	• Local accessibility • (Inter-)national accessibility • Availability of ICT-infrastructure • Sustainable, innovative and safe transport systems

Smart Environment (Natural resources)	**Smart Living (Quality of life)**
• Attractivity of natural conditions • Pollution • Environmental protection • Sustainable resource management	• Cultural facilities • Health conditions • Individual safety • Housing quality • Education facilities • Touristic attractivity • Social cohesion

[a] Not included in the empirical analysis of the smart city ranking.

Source: Adapted from Giffinger et al. (2007, p. 12), author's draft.

For a better understanding of the characteristics and factors of smart cities presented in Table 3 above, the list of the 74 detailed indicators that make these factors operational is attached in the appendix to this thesis (chapter 7.1).

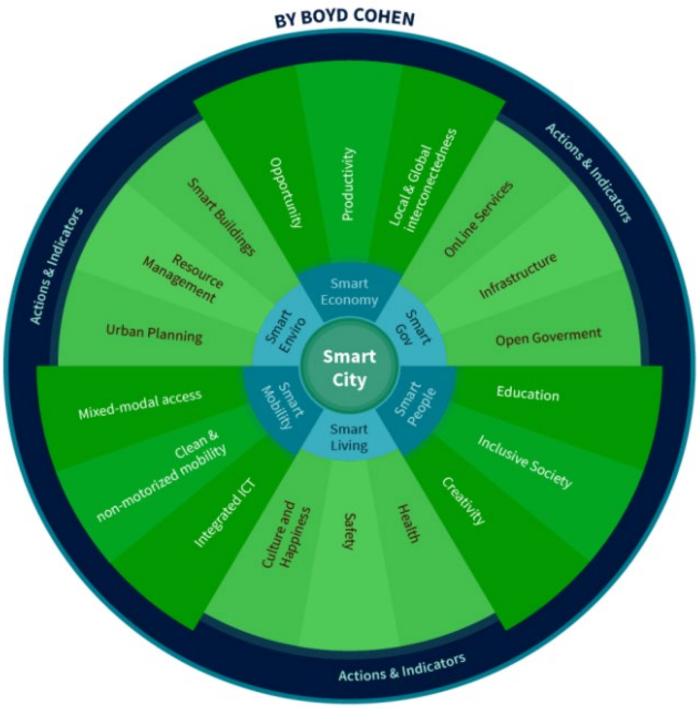
While this smart city concept and the aspiration to make it operational, and empirically measurable, is still one of the most prominent and comprehensive, it also has its limitations in terms of the consistency of the characteristics and factors. For instance, the factors of "social cohesion", "Pollution" and "Environmental protection" may be in conflict with some factors describing a smart economy. The trade-offs between these characteristics are rarely addressed, since the economic factors aim at improving and enhancing the competitiveness on the global markets by increasing labor market flexibility – a strategy that might reduce social security, and increase the number of precarious jobs in one-person businesses. The limitations of the smart city concepts presented in this thesis are further discussed in section 2.4.

2.3.2 Smart City Wheel according to Cohen

An approach and definition of smart cities, and ranking instruments rather similar to the ones by Giffinger et al. (2007; see chapter 2.3) is presented by Cohen (2014). The so-called "Smart City Wheel" shows the six main "dimensions" of a smart city which are in line with Giffinger's et al. (2007) characteristics (compare Table 3). In contrast, however, Cohen (2014) uses different subcategories compared to the ones used by Giffinger et al. (2007). Each dimension (Smart Environment, Smart Mobility, Smart Government, Smart Economy, Smart People and Smart Living) is therefore split into “Working Areas”, the latter into “Indicator Groups”, and these in turn into operational indicators (see Table 4). By this method, Cohen (2014) gives a definition of a smart city (not necessarily in the traditional sense of a scientific definition, but by listing numerous interdisciplinary fields contributing to the smart city concept) as well as the basis for rankings and assessments, respectively, of smart cities.

The Smart City Wheel (Figure 5) shows the applied dimensions as well as their assigned working areas.

FIGURE 5: SMART CITY WHEEL ACCORDING TO COHEN (2014)



Source: Cohen (2014).

Figure 5 serves as a basic overview and does not yet include all details of Boyd’s (2014) concept. Therefore, Table 4 presents the corresponding indicator groups being attributed to each working area.

Table 4: Benchmarking Indicators according to Cohen (2014)

Dimension	Working Area	Indicator Groups
Smart Environment	Smart buildings	Sustainability-certified buildings
		Smart homes
	Resource management	Carbon footprint
		Air quality
		Waste generation
		Water consumption
	Sustainable urban planning	Climate resilience planning
		Density
		Green space per capita
Smart Mobility	Efficient transport	Clean-energy transport
	Multi-modal access	Public transport
	Technology infrastructure	Smart cards
		Access to real-time information
Smart Government	Online services	Online procedure
		Electronic benefit payments
	Infrastructure	Sensor coverage
		Integrated health & safety operations
	Open government	Open data
		Open apps
		Privacy
Smart Economy	Entrepreneurship & innovation	New startups
		R&D
		Employment levels
		Innovation
	Productivity	GRP per capita
	Local and global connection	Exports
		International events held
Smart People	Inclusion	Internet-connected households
		Smartphone penetration
		Civic engagement
	Education	Secondary education
		University graduates
	Creativity	Foreign-born immigrants
		Urban living lab
		Creative industry jobs
Smart Living	Culture and well-being	Life conditions
		Gini index
		Quality of life ranking
		Investment in culture
	Safety	Crime
		Smart crime prevention
	Health	Single health history
		Life expectancy

Source: Adapted from Cohen (2014, p. 3), author's draft.

This systematic appears to be more refined, detailed and more coherent in content compared to the one by Giffinger et al. (2007). It is also evident that Cohen - not least due to the more recent date of publication - is more precise in addressing pressing smart city issues, such as resilience, climate change, carbon footprint, the use of smart devices (e.g., smart phones) and other thematic fields within smart city concepts.

Furthermore, Cohen (2014) links several operational indicators directly to ISO Standard 37120. The latter is attached in the appendix to this thesis (chapter 7.2; for a discussion, see also section 3.2).

As mentioned above, each element within the indicator groups is attributed to an operational and measurable indicator. As an example, “Carbon footprint” (element of the Working Area “Resource management” and, respectively, the dimension “Smart Environment”, see Table 4) is attributed to and measured by the operational indicator “Greenhouse gas emissions measured in tonnes per capita” (see Appendix, chapter 7.2). “Public transport” (as part of “Smart Mobility”) is measured by the operational indicator “Annual number of public transport trips per capita” (according to chapter 7.2)[7].

2.3.3 Smart City Indicator Set according to Sharifi (2019) and Ibrahim et al. (2018)

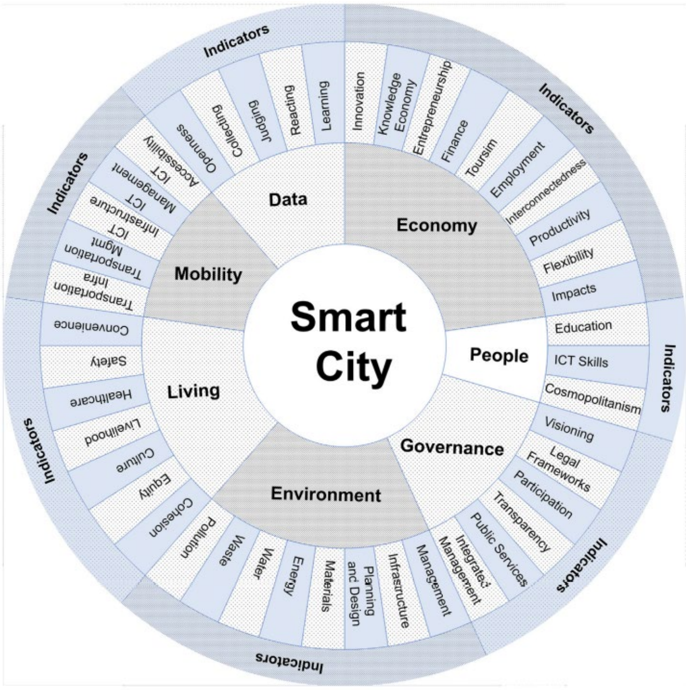
Sharifi (2019) also compiled – similar to Giffinger et al. (2007) and Cohen (2014) – the attributes of the smart city concept as a basis for reviewing smart city assessment tools and indicators. Sharifi (2019) follows the six main topics already mentioned (Economy, People, Governance, Environment, Living, Mobility; see also chapters 2.3 and 2.3.2) and adds a seventh category “Data” to his assessment scheme laid out in Figure 6 below. The latter is obviously due to the continuous development of ICT and the availability and significance of Big Data and opportunities developed from the latter. Ibrahim et al. (2018) abstain from including “Data” as a separate category since data and ICTs can be included in all policy fields. They rather label ICTs as “enablers” in the other policy fields.

Figure 7 presents the concept by Ibrahim et al (2018) who name their smart city concept the “smart sustainable city” for which technology is an enabling/supporting field.

This concept will be one important foundation of the empirical work of this paper; the operational indicators for the assessment and evaluation of smart city concepts are discussed in more detail in chapter 3.4. Therefore, a more detailed presentation and discussion will be provided below.

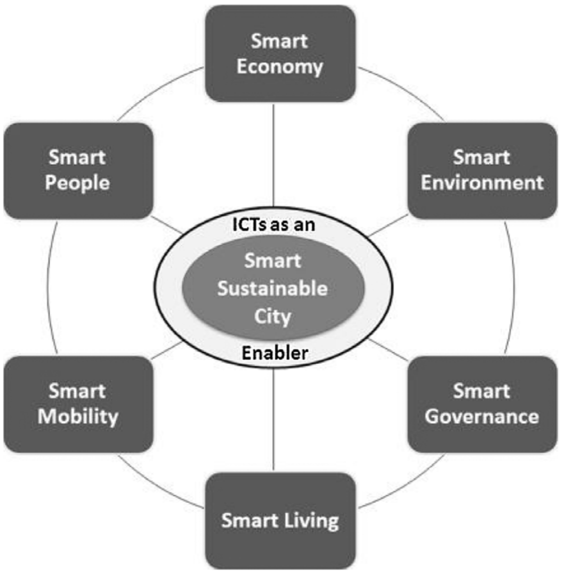
[7] Since these indicators are not further used in this work, a broader detailing is renounced and only examples are given.

FIGURE 6: SMART CITY INDICATOR THEMES AND CORRESPONDING SUB-THEMES



Source: Sharifi (2019).

FIGURE 7: SIX INDICATORS FOR A SMART SUSTAINABLE CITY



Source: Ibrahim et al. (2018).

2.4 Limitations and criticism of smart city concepts

The chapters above have laid out some of the most common definitions and concepts of smart cities developed and described in the scientific literature. Accordingly, smart city concepts originally intended to improve inter alia quality of life, increase urban innovation and economic productivity. The incorporation of sustainability was a rather subordinated and eventually incomplete goal of smart city concepts. Nevertheless, the concept of sustainability has become an indispensable factor for any smart urban development. For instance, policies against climate change, environmental issues, such as pollution or species decline, social topics like poverty and inequality, or land consumption, need to be included in such concepts. However, while ICT (and other) technologies might be necessary for achieving a sustainable development, the heavy focus of these concepts on technology is by far not sufficient in order to solve these major challenges. It is argued by numerous scientists that a truly smart city requires a holistic approach (see Alizadeh and Irajifar, 2018, Yigitcanlar et al., 2019b, Ibrahim et al., 2018). Yigitcanlar et al. (2019b) argue that cities cannot be smart without being sustainable. Furthermore, the authors find “little evidence that sustainability targets are achieved in cities that are recognized or claim to be smart cities” (p. 359). In a review of 35 scientific publications, Yigitcanlar et al. (2019b) lay out the following limitations and weaknesses of smart city concepts finding that the concept of sustainability, e.g., as defined by the United Nations in form of the Sustainable Development Goals (United Nations, 2021) has so far “not been adequately incorporated in the smart city practice” (Yigitcanlar et al., 2019a, p. 2).

Technocentricity of smart city concepts: Actual urban smartness derives from citizens, policy makers, planners and city administrators, not from an overuse of ICT technology (see also Morse, 2014). Since urban sustainability is a highly complex phenomenon and requires a multidisciplinary approach, a mere focus on technical solutions is not sufficient. An example is given by Lom and Pribyl (2020). Although they consider the smart city concept from a highly technical perspective, they argue that a mere collection and dissemination of data to certain users can be even detrimental. For instance, smart parking technology might even lead to more traffic as multiple drivers receive information about available parking spaces. Nonetheless, the goal of smart cities would not be to ignore technical solutions, but to invest public funds wisely. In this regard, the authors also refer not only to the exploitation and depletion of rare earth metals and the inability to avoid or trace conflict resources in technology-driven smart city investments, but also to electronic waste being dumped in Africa or China under questionable circumstances.

The lock-in effect already in chapter 2.2.4 mentioned imposes the danger of potentially costly, necessary and regular updates or upgrade investments making communities dependent on the provider initially chosen. Besides this “technological lock-in”, Kitchin (2013, p. 12) goes on to cite further issues such as ethical questions with regard to big data analytics, surveillance and data control regarding data quality and security (“corporatized government”, p. 12).

Therefore, Yigitcanlar et al. (2019b) raise the question: “What are the appropriate technologies and the right amount of technocentrism to bring sustainability to our cities?” (p. 359).

Complexity of smart cities: Referring to cities being "systems of systems" (see also chapter 2.2.2) and therefore, being complex in the sense of "sophisticated, intricate and complicated" (p. 359), Yigitcanlar et al. (2019b) see urban policymakers being pushed to choose short-term solutions providing short-term profits by opting for technologies from corresponding IT enterprises instead of dealing with the complex structures of a city. According to Ibrahim et al. (2018) practitioners oftentimes fail to analyze "the current economic, social, environmental, and political state and challenges of a city" (p. 532). As a result, Yigitcanlar et al. (2019b) raise the question: "Will the future city models be able to manage the currently unmanageable complexity of the city?" (p. 359).

Further, due to the fact that smart city concepts are fuzzy and so far no comprehensive and distinctive definition exists, some differentiations of city concepts (e.g. "traditional" versus "smart" cities) are questionable as "traditional" cities without a techno-centric planning focus can be just as sustainable and smart (compare the notion of Lom and Pribyl, 2020, versus Yigitcanlar et al., 2019b).

Ad-hoc conceptualization of smart cities: Yigitcanlar et al. (2019b) further raise the concern of a lack of profound smart city concepts. This lack is not only due to the above-mentioned danger of technocentricity and the given complexity of city structures, but mostly due to the divergence between smart city goals and actual sustainable urban development goals. With respect to the concept of sustainability, reference needs to be given to the generally recognized 17 UN Sustainable Development Goals. According to the United Nations (2021), the concept of sustainability "promote[s] prosperity while protecting the planet". The 17 Sustainability Goals (see Figure 8) "recognize that ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection. More important than ever, the goals provide a critical framework for COVID-19 recovery".

FIGURE 8: THE 17 UNITED NATIONS SUSTAINABLE DEVELOPMENT GOALS

Source: United Nations, 2021.

In contrast to the UN concept of sustainability, the smart city notion is viewed by numerous scientists as a concept that “reinforces neoliberal economic growth, focusses on affluent populations, disempowers citizens, neglects environmental protection, and fails to challenge or provide real alternatives to the prevailing consumerist culture” (Yigitcanlar et al., 2019b, p. 359). One of the central reasons for this is the lack of a generally valid definition of the smart city idea including a corresponding detailed concept (see e.g., Letaifa, 2015 and chapter 2.2.1). The intended purpose of the smart city idea is sustainable urban development, at least in theory. In practice, Yigitcanlar et al. (2019b) state (by referring to Balducci and Ferrara, 2018, and Serbanica and Constantin, 2017) that smart and sustainable city concepts have been often used solely for decorative purposes or reduced to secondary topics. In connection with the above-mentioned aspect of techno-centricity, the authors define the following opposites as challenges in the smart city notion – “short-termism vs. long-term gains, elitist vs. inclusive, profit-driven vs. equilibrium-driven, business-friendly vs. environmentally-friendly, carbon-economy vs. climate-neutral-economy, materialism vs. dematerialsim and so on” (p. 360). An example is given by Papa et al. (2017) – their research on smart mobility strategies in Italy found that investments in smart mobility have increased inequalities between the Italian north and the south. Therefore, Yigitcanlar et al. (2019b) raise their third main question with respect to the smart city notion: “Are self-claimed comprehensive smart city conceptualizations comprehensive enough to be able to tackle the unsustainable development problems of our cities?” (p. 360).

With respect to the three main limitations mentioned above, it will be necessary for urban administrators and policy makers to follow a broader planning approach beyond technocentricity and to include more holistic planning methods to tackle the urgent urban topics. Further, it will be indispensable to agree on a general and operational definition of the smart concept. The bottom line is that the UN’s catalog of the 17 sustainability goals will inevitably have to be incorporated into any smart city concept (see Yigitcanlar, 2019b, and United Nations, 2021).

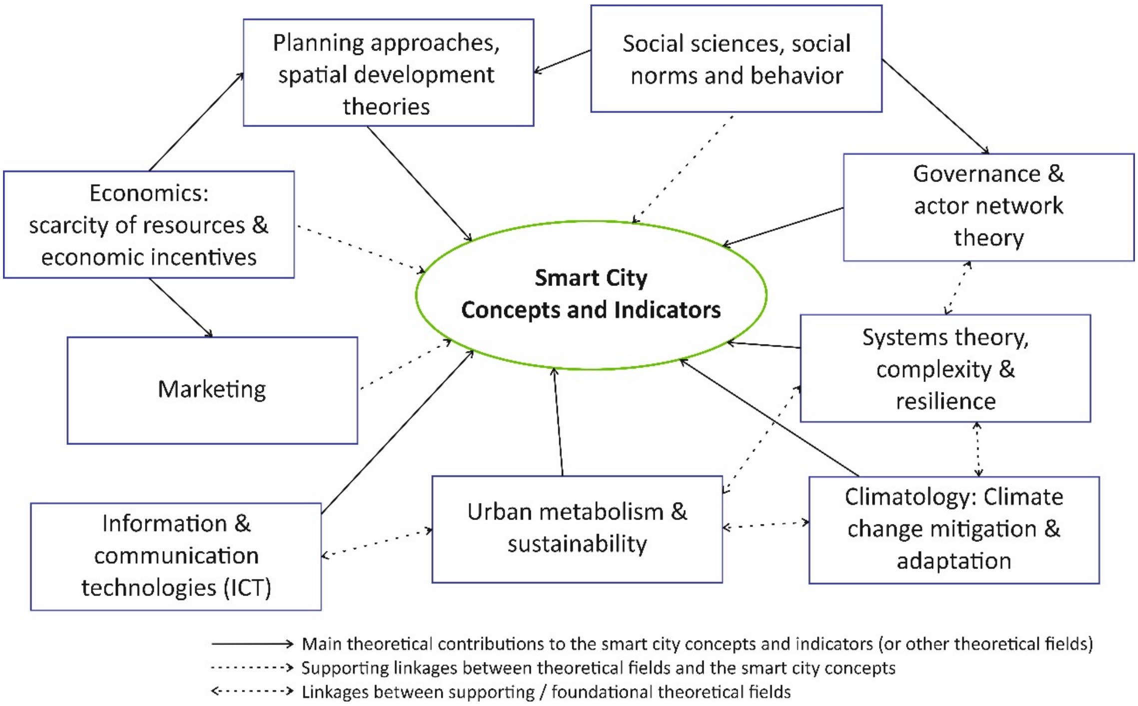
2.5 Embedding the smart city concepts in theoretical concepts

The sections above showed the diverse smart city concepts developed by different scholars and stakeholders, respectively, as well as smart city concepts being used as the underlying basis for rankings, and finally, a critique depicting the limitations of smart city concepts.

In order to understand smart city concepts in detail, it is essential to understand the theories behind. In section 2.2.2 cities were discussed as systems of systems, which in turn shows how interconnected the individual structures respectively elements of a city are. Therefore, not a single theory will be central and decisive. The individual concepts are numerous, stem from different scientific disciplines and are interconnected with each other.

The following Figure 9 shows selected disciplinary concepts and their interconnections used for this thesis. The different arrows are meant to show possible connections and underpinnings of the smart concepts, as well as of other theoretical fields. The following sub-sections will describe the main theoretical fields and their connection to the smart city notion. The interdependencies between the individual theoretical fields is not subject to this thesis.

FIGURE 9: SELECTED THEORETICAL CONCEPTS IN CONNECTION WITH THE SMART CITY NOTION



Source: Own concept, 2021.

This chapter is intended to provide a short overview of each theoretical approach, and how it relates to smart city concepts. The overview of theories is necessarily not exhaustive and only very briefly describes the different disciplinary approaches to defining smart cities and their indicators for measuring the smartness of a city.

2.5.1 Social sciences, social norms and behavior

There is a growing understanding in the scientific literature that individual decision-making and individual behavior has direct implications on environmental challenges especially in the urban context. Tackling urban environmental problems can only be done through the involvement of the local citizens and must encourage individual, environmentally friendly choices. Research in this respect has laid a focus on socio-economic, spatial and psychological as well as behavioral approaches showing that increased environmental concern and awareness is directly connected with environmentally responsible individual decisions (Atshan et al., 2020).

Further, Atshan et al. (2020) show that social trust is part of the social capital concept (see also section 2.2.5) in the sense of social capital being “the collective norms, trust, social connectedness, and reciprocity from which all actors can benefit” (p. 331). Social capital is considered as the key element to environmentally responsible behavior. The authors have further shown that "community participation and strong ties" (p. 336) also relate positively to environmentally responsible behavior and as such, contribute to urban sustainability.

The smart city concept as developed, for instance, by Sharifi (2019), closely refers to the importance of social capital, norms and behavior by including, in particular, the field of "smart people" as a key element in his approach. Smart cities therefore rely both on environmental attitudes and awareness for the development and implementation of policies.

2.5.2 Governance and actor network theory

The role and influence of governance respectively smart governance within the smart city notion has been widely discussed and measured by numerous scholars. Filho et al. (2016) explore the connection between governance and sustainability in the sense of setting governance principles towards establishing sustainable societies. Their definition of sustainable governance is "a modality of governance which takes into account the principles of sustainable development. In other words, a governance system where the integration of sustainability into the business and management model is used, providing added value to citizens as shareholders" (p. 755f). Further, governance that follows sustainability principles is seen as a key factor for achieving the UN Sustainable Development Goals (SDG).

Filho et al. (2016, p. 758) apply the following indicators to their research of analyzing sustainability governance.

- "Voice and accountability
- Political stability and absence of violence/terrorism
- Government effectiveness
- Regulatory quality
- Rule of law
- Control of corruption" (p. 758).

De Guimarães et al. (2020) argue in a similar way by attributing smart governance factors to the quality of life (QoL)[8]. According to the authors, smart governance depends on and positively relates to the following "constructs" (p. 3): "Transparency" (as an instrument of citizen empowerment, fight against corruption, accountability and decision-making), "Collaboration" (active participation with the government, debates with citizens), "Participation and Partnership"

[8] De Guimarães et al. (2020) define Quality of Life (QoL) as "positive situations that result in citizens' cognitive, subjective and affective well-being" by referring to Carvalho et al. (2018) and Florida et al. (2013).

(partnerships with the private sector, educational institutions, communities and other stakeholders), “Communication” (fosters transparency; use of technology to increase efficiency of communication) and finally, “Accountability” (in direct relation to commitment of public decision makers).

The importance of social networks for policy-making and governance has recently been reviewed by Bodin and Crona (2009). According to the authors, natural resources are often resources that are shared by many stakeholders, and therefore can rarely be conserved and managed by top-down policies. Rather, a (social) network of different kinds of actors is part of the governance system for the resource. While formal institutions and legal provisions form the frameworks of management, the collaborative processes in networks, e.g., by the inclusion of the stakeholders’ knowledge, can improve the achievement of policy objectives. The empirical analysis of social networks uses measures of the nature and intensity of the connections, and the distance between actors, among others. Furthermore, the actors are defined by their centrality in the network, leading to hierarchies within the network (e.g., core vs. periphery). Reciprocity and trust in a network increase the quality of policy processes as well (Valente et al., 2015).

The analysis of social networks (SNA) “is both a theoretical perspective on how the interactions of individual autonomous actors form the social structures of community and a set of analytical tools to analyze […] nodes (actors) and ties (relationships)” (Dempwolf and Lyles, 2012, p. 4). A recent empirical example of an empirical SNA referring to the planning and implementation of urban green infrastructure in one of the cities chosen as a case study for this thesis, Vienna (see chapter 4), has been provided by Bogadi (2020). The author shows how the various actors – e.g., municipal departments, experts, citizens – are linked together in a social network. The aim of such analyses is therefore to study such networks in order to improve policy outcomes by strengthening the crucial components in the network, and by improving the linkages between the actors.

While the elements of smart cities in regard to technical/smart networks and grids are obvious, the connection between the smart city concept and social network theory and analysis is a priori less visible. However, empirical studies such as the one by Bogadi (2020) clearly infer that the development of smart city concepts, as well as the implementation of policies in the diverse urban policy fields, cannot merely be considered as top-down activities. The success or failure of policy implementation depend on robust and able social networks connecting city departments, planners and experts, citizens, and various other stakeholders (Bodin and Crona, 2009). Social networks – and urban governance – can therefore be considered as substantial theoretical underpinnings of the smart city concept.

2.5.3 Systems theory, complexity and resilience

Lom and Pribyl (2020) refer to the systems theory (see also chapter 2.2.2) in the context of the smart city notion by defining cities as “dynamic and nonlinear systems” (p. 1) consisting of a number of systems which again can be split into numerous subsystems such as e.g., transport systems, housing, sanitation or businesses.

By adding the technological systems to the concept mentioned before, Eremia et al. (2017) view cities as having horizontal and vertical infrastructures respectively systems, for instance, with a smart grid enabling the systems’ functions and ICT providing the basic infrastructure.

As such, smart city concepts heavily lean on systems theory, especially the complexity of systems and subsystems, and the urban system’s resilience (Davoudi, 2012). Two main references to the smart city concept – as it is operationalized for the purpose of this thesis in section 2.6 – should be mentioned here. Firstly, conceptualizing a smart city is based on an understanding of the linkages between the different urban subsystems such as the energy, environmental and mobility systems on the one hand, and the social and political systems on the other hand. Secondly, an important element of the smartness of a city is its resilience towards shocks, especially in regard to climate change, rapid economic and technological disturbances, as well as migration and demographic changes (see Davoudi, 2012).

2.5.4 Climatology - climate change mitigation and adaption

Climate change mitigation and adaption have become equally important and urgent requirements to tackle the climate crisis. Climate change mitigation is defined as “a human intervention to reduce the sources or enhance the sinks of greenhouse gases” (IPCC, 2014, p. 1266). Climate change adaption is defined as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities (IPCC, 2014, p. 1251)”.

Due to the fact that cities are dense structures (see also section 2.5.9), they can be strong drivers for per-capita reductions in energy use and greenhouse gas emissions (Angel et al., in press). According to Grafakos’ et al. (2020) systematic assessment and literature review city climate policies can contribute to bring comprehensive benefits, enhance synergies and reduce conflicts which again would potentially lead to more cost-efficiency and less maladaptation or malmitigation.

Maladaptation – in the context of climate change – is defined as “negative effects that are as serious as the climate-induced effects being avoided” (Magnan, 2016, p. 648). Another definition for maladaptation is “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups” (Barnett and O’Neill, 2010, p. 211). An example for maladaptation is the use of resources or devices that further increase greenhouse gas emissions (e.g., air-condition devices implemented to tackle the issue of urban heat-waves) (Barnett and O'Neill, 2010). Malmitigation is referred to "increasing risks from mitigation" (Grafakos et al., 2020, p. 2). An example for malmitigation within the smart city notion is the implementation of numerous sensors and their need to be regularly renewed in connection with questionable sourcing of rare earth metals or child labor (see e.g., Lom and Pribyl, 2020).

Combining climate change and urban microclimate issues and with smart city planning results in the concept of the UN's 17 Sustainable Development Goals (SDGs), with special emphasis on SDG #7 (Affordable and Clean Energy), #11 (Sustainable Cities and Communities) and #13 (Climate Action) (United Nations, 2021; Mauree et al., 2019).

In addition, Mauree et al. (2019) have shown that - when it comes to proper design, siting, and building orientation-, it is essential to consider the city "as a complete ecosystem with a complex metabolism" in the course of planning for the profitable use of solar and microclimatic aspects (p. 741). The authors compiled a list of parameters to be considered in urban planning and design with respect to climatology: Built form, density and type of buildings (e.g., air flow, sun position, surface area); the width-to-height ratio and orientation of the street canyon; design of buildings; urban material and surfaces; green (e.g., trees, parks, lawns) and blue (water elements) infrastructure; traffic-related topics, integration of renewable energy sources and overall topics arising from climatological extremes (Maureen et al., 2019).

The carbon footprint is a further important notion within the smart city discussion. Two aspects are of particular importance.

Firstly, it should be noted that the carbon footprint consists of two main categories - the indirectly triggered emissions of households through the consumption of products (referred to as Emissions Embodied in Consumption (EEC)) and the direct household emissions originating from, for instance, heating or private transport (see e.g., Muñoz et al., 2020; Ala-Mantila et al., 2014).

Secondly, urbanization is a central but also complex phenomenon contributing to the urban carbon footprint. Effects triggered by urban densification, housing and industry, but also lock-in effects due to given infrastructure have an impact on the carbon footprint. The scientific discussion on this is broad. Studies that focus on high-income economies find that compact urban structures contribute to lower per capita emissions compared to rural areas. This is due to denser living with less space consumption and smaller apartment sizes, the presence of public transport and shorter commutes (Muñoz et al., 2020; Ala-Mantila et al., 2014). Nevertheless, it can be argued that the high-consumption lifestyle of city residents can contribute significantly to the energy-use, especially when indirect emissions of products consumed are also taken into consideration (Ala-Mantila et al. 2014).

In regard to smart city concepts, the connections with the several dimensions discussed in this section can be summarized as the options and effectiveness of mitigation and adaptation measures. In addition, the carbon footprint, among other concepts, is an important indicator for the achievement of urban sustainability goals.

2.5.5 Urban metabolism and sustainability

The conceptualization of a city as a system of inputs, throughputs, and outputs was prominently discussed by Newman (1999) who defined cities as complex and dynamic urban ecosystems. When analyzing a city and tracking how energy, material and waste move, it is possible to conceptualize "management systems and technologies which allow for the reintegration of natural resources, increasing the efficiency of resource use, the recycling of waste as valuable materials and the conservation of (and even production of) energy" (p. 220). Further, Newman (1999) established an „Extended Metabolism Model of the City" (p. 220) by defining metabolism as "a biological systems way of looking at the resource inputs and waste outputs of settlements" (p. 220). This approach consists of "Resource Inputs" such as e.g., land, water, food, energy, building material which are subject to "Dynamics of Settlements" (including transportation, economic and cultural priorities) which again result in "Livability" (health, employment, income, education, housing, leisure activities, accessibility, urban design quality and community) respectively "Waste Outputs" (p. 220). The author compares a city with a human body, where products and waste are created by physical and biological metabolic processes. Therefore, applying this notion to a city, it follows that the laws of thermodynamics ensure that everything that goes into a system comes out at the end, and the amount of waste depends on the amount of input. Consequently, Newman (1999) therefore emphasizes that the most efficient way to reduce a certain (negative) impact is to reduce the resources put into a system.

D'Amico's et al. (2020) approach provides the connection to "smartness" by embedding the principles of the traditional urban metabolism into a holistic approach. According to the authors, "smart urban metabolism" is a hybrid approach, where technological, economic, environmental and social perspectives are simultaneously considered, and that develops smart and sustainable cities" (p. 1). By this, the authors' theory of smart urban metabolism[9] is the bridging concept to the notion of smart cities by addressing recent urban issues such as urbanization, environmental and governance topics or the efficiency-based application of ICT systems. Cities are to be considered as "open ecosystems" which again are seen as "complex urban metabolism[s]"

[9] D'Amico et al. (2020) list for their model of urban metabolism the following indicators as relevant: Economy, education, environment, governance, health, housing, population and social conditions, recreation, safety, solid waste, sport and culture, telecommunication, transportation, agriculture, urban planning, wastewater, water (p. 5).

consisting of “social, environmental, economic, governance, and technological interactions among several internal and external actors” (p. 1). This results in broad urban issues that can, however, only be solved with limited resources. “Consequently, computerization, digitalization, and efficiency of urban processes have become a priority for the development of livable urban settlements; where the concept of ‘smart urban metabolism’ allows us to achieve that goal” (D’Amico et al., p. 1).

Regarding sustainability, there are several coexisting concepts available in the literature. The most prominent one stems from the Brundtland Report claiming sustainability as a “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 43).

Another sustainability concept stems from IUCN/UNEP/WWF (1991; cited in Hacker et al. (2004, p. 284)) by referring to the quality of living and available capacities (and therefore going beyond pure “needs”): “Sustainable Development means improving the quality of human living within the carrying capacity of the supporting eco-system.”

The Gothenburg European Council (European Commission, 2001; cited in Hacker et al., 2004, p. 284) refers to sustainability by emphasizing the underlying resources, i.e., economic, human and natural capital: “Sustainable development requires dealing with economic, social and environmental effects in a mutually reinforcing way.”

The operational definition of a smart city presented in section 2.6 below refers to the urban metabolism by including the notion that both a smart and a sustainable city are necessarily inseparable concepts. “Smart” in its technological sense could therefore refer to the improvement of the efficiency of urban processes (e.g., by using less resources per unit of output or income), while in a “sustainable” city, the ecological limits are observed (in the meaning of sufficiency and de-coupling of social and economic development from the total amount of resources used). The latter directly links to the concept of urban metabolism since unwanted emissions of waste, heat, or sewage, can only be reduced significantly by a smaller material input.

2.5.6 Information and communication technologies (ICT)

Bifulco et al. (2016) define ICT as “a relevant tool or as the key to addressing smart processes” (p. 133). Further, the authors see ICT as the enabler of smartness in the technological sense as well as simultaneous compliance with the sustainability concept being “across-the-board elements” connecting “the services provided to communities in a smart city and play a key role in smart city planning” (p. 132).

Despite the fact that there is no generally acknowledged definition of smart city, all concepts show that ICT is a relevant element or even major contributor and consequently appears in all definitions. Nevertheless, the level of importance assigned to ICT is seen in various bandwidths among scholars. The range last from purely technology-driven views to a supportive and to a subordinated importance (see 2.2). However, even if an approach to the smart city concept is adopted on the basis of sustainability, ICT may contribute significantly to the achievement of many sustainability and smart city goals. Camero and Alba (2019) connect the six fields of the smart city concept (smart economy, environment, governance, living, mobility, and people) to the specific use of ICT.

In the field of a smart economy, the production of knowledge, dissemination of information, e-commerce, and smart industrial processes may be enhanced by the use of ICT (for this and the following arguments, see Camero and Alba, 2019, p. 86). Regarding a smart environment (e.g., climate change mitigation, urban energy use and metabolism), smart metering, smart grids, monitoring of energy use and smart buildings, all include relevant ICT components, or may be considered as core urban ICT infrastructure.

Smart governance may include ICT in order to enhance the efficiency of administrative processes, and facilitate e-participation and the distribution of relevant knowledge to citizens. Smart Living understood as the aim to make a city more livable, includes new lifestyles and ways of consuming, e.g., digital goods and services (Camero and Alba, 2019).

Smart mobility is certainly one of the core fields of ICT, for instance, in regard to managing public and private transportation, and developing new forms of logistics. Finally, ICT can support creative and learning processes, promote working from home, and in general improve human and social capital in the field of smart people.

Besides the specific contributions of ICT to the smartness of a city, there is some underlying digital infrastructure that can provide the hardware and software for the above-mentioned fields. For instance, the technical lines of communication (fiber optics, networks) are important as well as the initiatives of cities to provide open-source software and open government data as private households as well as consumers can develop their own smart solutions (Neves et al., 2020).

2.5.7 Marketing

Studies on smart city marketing mostly target topics related to smart tourism – only few scholars include the local residents in their research. According to Braun et al. (2013) the local residents are among the most neglected groups in city marketing although they are respectively are supposed to be active stakeholders within a smart city framework. Braun et al. (2013) emphasize the importance of including and consulting residents in marketing efforts in order to achieve a more effective brand communication. The authors assign residents three distinct roles within a marketing strategy – residents are to be seen as “an integral part of the place brand” based on their attributes and behaviors, as “ambassadors for their place brand who grant credibility to any communicated message” and as “citizens and voters who are vital for the political legitimization of place branding" (p. 18). This view is supported by Belanche et al. (2016) by stating that a "relationship marketing perspective" (p. 75) is most relevant for public administrators to create a closer relationship between a city and its citizens. As a result, a positive affinity with the city leads to a higher acceptance of environmental programs and city activities.

Nevertheless, the marketing measures of a city should not be a central point of a smart city strategy in order not to run the risk that the smart city concept becomes an empty marketing shell. In this respect, Vanolo (2014) argues – with respect to the lack of a generally accepted concept respectively definition of a smart city (see also section 2.2.1) – that the term "smart city" is in danger of degenerating into an advertising slogan serving stakeholders to advocate their own goals which might not be in line with, e.g., an overarching sustainability agenda (compare e.g. an industry-driven and techno-centric approach to the smart city concept according to the framework laid out in chapter 2.2.4).

2.5.8 Economics: scarcity of resources and economic incentives

Of the numerous economic theories and approaches, there are some that are of particular importance for the smart city concept. As this thesis conceptualizes a smart city as also fundamentally being a sustainable city, economic approaches considering the environmental and ecological limits to growth are certainly of specific significance. One of the major economic approaches that takes up the *scarcity of environmental resources*, refers to the urban metabolism as a city's physical flow model (see section 2.5.5). Therefore, notions of smart/green/sustainable growth, and *de-growth*, may form one of the key elements of economic theories of smart cities.

There is, of course, a decades-long debate on whether economic growth may be prolonged with limited natural resources (the concept of "The limits to growth", Meadows et al., 1972). However, the question whether economic growth is feasible in the long term is an empirical as well as a theoretical question. Numerous studies have been published on the connections between economic growth and resource use. Steinberger et al. (2013) have recently published a worldwide study and found that the use of material resources significantly grew with increases of GDP (gross national product).

De-growth is, among other schools of thought, a (normative) economic theory that proposes to replace quantitative indicators of economic development (e.g., GDP growth rates) by qualitative indicators (e.g., quality of living) with the aim to increase well-being or happiness for all humans within the limits of sustainable resource use, and to provide a fair distribution of income and wealth. Therefore, de-growth is "a process of political and social transformation that reduces a society's throughput while improving the quality of life" (Kallis et al., 2018, p. 292).

Given the robust empirical evidence on the connection between growth and resource use (Steinberger et al., 2013), it seems questionable whether a smart city can – theoretically – be also a city that accounts for smart respectively sustainable growth. Closely connected to this question is the notion of increasing the (international) competitiveness of smart cities (Dziembała, 2019; Camagni, 2002). In fact, some neo-liberal scholars could argue that the smart city concept is basically a concept to boost economic growth, and to market the city as an attractive location for companies. Environmental policies that are regularly included in smart city concepts such as improving the efficiency of resource use, and attracting economic branches with a high economic output while using less resources (e.g., service sectors such as R&D, financial services), may lead to a relative decoupling of growth and resource use. However, it is questionable whether economic activities can grow while at the same time reducing the environmental burden. The underlying concept for this notion is the "Environmental Kuznets Curve" defining the relationship between e.g., different pollutants and economic growth or income as an inverted U-shape (Dinda, 2004).

Given the problems of resource-intensive growth, a further theoretical concept that is closely linked to the smart city concept – understood as a sustainable smart city – is the notion of a *circular economy* (Fratini et al., 2020). The circular economy "is a concept that seeks to promote a sustainable way of living, where resources are used more efficiently and are retained in the economy for as long as possible. The latter can be achieved by creating loops that feed resources back into the system for use in same or new components and products with the same or lower functionality." (Hahladakis et al., 2020, p. 481). The European Commission has recently put forward an action plan detailing the strategies to promote a circular economy in regard to diverse economic issues such as sustainable products and production, waste management, and the consideration of production and value chains (European Commission, 2020).

The circular economy concept is therefore an integral part of those smart city strategies and concepts that deal with issues of sustainability and the limitation of resource use, emissions and waste.

Similar to the circular economy, the concept of a *sharing economy* is also in close relation to the smart city notion. The sharing economy is referred to as "an emerging economic model usually defined as a peer-to-peer based sharing of access to goods and services, which are facilitated by a community-based online platform. It focuses on the sharing of underutilized assets in ways which improve efficiency, sustainability and community" (Mi and Coffman, 2019, p. 1; Akande et al., 2020). In relation to the sustainability notion (see also section 2.5.5) Dabbous and Tarhini (in press) summarize in their literature review the different approaches ranging from the position that the sharing economy contributes to cost-sharing and decreases inequality to relativizing the actual impact on sustainable economic growth respectively questioning the fostering of sustainability in principle. The sharing economy is also under criticism as it might lead to the undermining of legal regulations (e.g., working conditions and wages) as well as to the emergence of monopolies of sharing economy companies. Further criticism relates to neo-liberalism "misusing the concept of entrepreneurship" (Dabbous and Tarhini, in press, p. 3).

The concept of "*territorial competitiveness*" (Camagni, 2002) is a further theoretical element closely linked to some important notions of the smart city concept. For instance, Camagni (2002, p. 2396) does not only refer to technological innovations as part of policies towards territorial competitiveness, but also considers the economic and social relations (e.g., relational or social capital), and the governance system as promoting competitiveness. As discussed in this thesis, many conceptual approaches to the smart city implicitly consider these elements.

Several other theoretical economic concepts such as the development towards a *knowledge-based economy* (Penco et al., 2020) or approaches of development understood as *co-evolutionary processes* (Schaltegger et al., 2016)– social, economic and ecological systems evolving in parallel and complementing each other – may additionally be important for smart city theories and concepts.

2.5.9 Planning approaches, spatial development theories

There are, of course, also numerous theoretical concepts concerning the development of cities, urbanization, and planning. However, in regard to the smart city concept, the following four theoretical approaches in planning belong to the most relevant ones.

The first one concerns the smart city concept in the framework of "planning approaches". A planning approach consists, theoretically, of a certain perspective on the spatial problem to be solved, an objective and overall goal of planning, the methods applied in planning and development, and the background knowledge of various disciplines (Schönwandt and Voigt, 2005).

As such, a smart city concept may be conceptualized as a planning approach since it comprises of urban or regional problems to be solved (e.g., lack of social inclusion, overexploitation of resources), aims and objectives (e.g., urban sustainability), and the methods applied (e.g., design of new participatory frameworks, social innovations).

However, a second important theoretical underpinning of smart urban planning is the understanding of planning as tackling spatial problems. This view was labeled as the "problems first" approach as the starting point in planning (Schönwandt, 2020). Key to planning within the smart city framework is the understanding that certain problems are to be solved by, for instance, extensive and inclusive participation frameworks. Interestingly, many smart city concepts – as has been shown in the review of the literature in the sections above – have focused primarily on technological innovations, e.g., for smart grids or smart metering. The neglect of basic planning concepts such as the one by Schönwandt (2005) in this case shows that the mere implementation of ICT – without considering spatial and urban problem solving – may be driven by large tech companies and consultants lacking urban planning competences and contradicting broader sustainability goals.

A third basic concept of planning is the notion of compactness of cities, and of urban structures that minimize, for instance, the inputs of resources, the use of energy for mobility, and the carbon footprint of agglomerations[10] (see Angel et al., in press).

Finally, the “sustainability planning paradigm” (Kohon, 2018) is based on the notion that planners, on the one hand, are faced with real-world urban structures and the results of past approaches of development and planning. On the other hand, planners provide concepts and solutions to spatial problems, which in turn may lead to desired but also unwanted social, ecological and economic outcomes.

2.6 Operational definition of the smart city concept used in this thesis

The previous sections of chapter 2 gave an introduction of the history of the smart city notion, laid out the smart city concepts most frequently cited in the scientific literature and provided an overview of some key smart city rankings which each provide themselves a definition of the corresponding smart city notion. Further, limitations, criticism and underlying theories have been discussed.

In order to proceed with the methodological part in chapter 3 and the empirical part in chapter 4, it is necessary to establish a separate operational definition of a smart city concept. The subsequent reflections are the author’s own concept but refer mainly to Giffinger et al. (2007), Cohen (2014), Sharifi (2019), Yigitcanlar et al. (2019a) and Yigitcanlar et al. (2019b).

The understanding of the author of this thesis is that a smart city is a city based on the concept of sustainability and, in particular, on the 17 Sustainable Development Goals provided by the United Nations allowing for sustainable urban development. To make a sustainable city smart, it is further understood that information and communication technologies are an integral part of a smart city concept and ensure the support and technical implementation of the SDGs. Without the fundamentals of sustainability, a “smart city” would only be a techno-centric or digital city.

Furthermore, a smart city is also a resilient city that can cope with short term shocks and long-term challenges such as climate change, pandemics or migration, for instance.

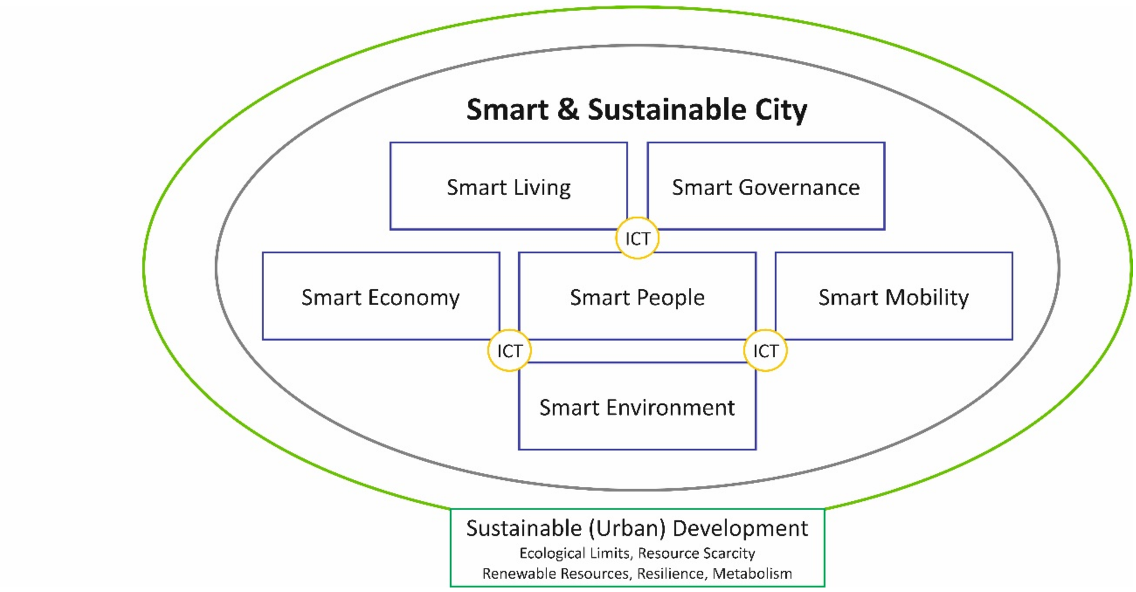
Sustainability, resilience and the use of ICT are understood as the basic planning principles in the following six categories:

[10] This notion applies mainly to western countries. In less developed countries urban density might lead to problems in e.g., water supply, traffic congestion, sewage and hygienic issues or inadequate escape routes and access for rescue operations (Angel et al., in press).

- Smart People,
- Smart Environment,
- Smart Governance,
- Smart Economy,
- Smart Living, and
- Smart Mobility.

Finally, a smart city is never in a complete state of smartness, but is always evolving, innovating and adapting. The following Figure 10 aims at displaying the main elements and the understanding of both sustainability and the supporting role of ICT.

Figure 10: Graphic representation of the smart & sustainable city concept used in this thesis



Source: Own concept, 2021.

The framework for a smart *and* sustainable city is, of course, given through the ecological limits in the sense of sustainable (urban) development. Important ingredients are, among other elements, the scarcity of resources (land, natural resources), the use of renewable resources, the resilience of ecological and human systems, and the concept of metabolism (flows of matter and energy). The smart city is necessarily embedded in this ecological framework and concentrates on the six fields (dimensions) that are of particular importance for sustainable urban development. ICTs are meant to *support* the goals of a smart and sustainable development, and to *link* the different fields (dimensions) with each other. In such a concept, growth and development is only feasible within the ecological limits; the quality of urban life may develop and increase over time given these limits.

The next section first presents the methodology of evaluating smart city concepts, and then presents a set of indicators and an evaluation approach that has its foundations in the operational definition of the smart city concept developed above.

3 METHODOLOGY

3.1 Introduction

This chapter provides an overview of the methodology for the analysis of smart city concepts. The definitions and concepts discussed above in section 2 infer that there is a wide variety of conceptual underpinnings and meanings to the terms of smart cities, each of them depending on the viewpoints of the corresponding stakeholders. As the smart city concept developed over time, numerous sets of areas respectively, fields and indicators have been presented. The aim of this chapter is, therefore, to provide a clear understanding of the analysis of smart city concepts, and the selection of cities to be studied in this thesis. Finally, the operational concept of a smart sustainable city developed and presented in section 2.6 will be used to design the evaluation framework (including indicators for a conceptual evaluation).

3.2 Selection of methodology: Methodological foundations of the analysis of smart city concepts

As described above in the introduction of this thesis, the comparison of three selected smart city concepts of European cities is the main topic of this thesis. The comparison of concepts is not as straight-forward as an empirical application of pre-defined sets of indicators such as the ones by Giffinger et al. (2007), Boyd (2014) or Sharifi (2019). Furthermore, the International Organization for Standardization (ISO) has published two ISO standards for the assessment of sustainable and smart urban development (ISO 37120:2018 ("Sustainable cities and communities — Indicators for city services and quality of life") and ISO 37122:2019 ("Sustainable cities and communities — Indicators for smart cities")). As described above, these two ISO publications include a broad range of indicators to evaluate the smartness of cities. Mattoni et al. (2020) and Escolar et al. (2019) provide examples of quantitative and multicriteria (multidimensional) methods of assessing the rankings of cities in regard to their smartness.

Multidimensional and multicriteria approaches, however, are better suited as the methodological foundations of a comparison of the selected smart city concepts than pre-defined quantitative indicator sets. A conceptual comparison does not provide answers to the question which city can be considered more or less "smart" (defined by the quantitative indicators) from an empirical perspective. The conceptual comparison rather provides a more abstract analysis on the level of strategies and objectives of urban development, and assesses the existence of the dimensions of smart cities in the respective urban concepts and strategies (Ameen and Mourshed, 2019).

As such, the comparative approach is based on multiple criteria, which are usually described verbally or with a qualitative/hermeneutic method.[11] Nevertheless, a comparative assessment (evaluation) of concepts is based on the following elements (Hanusch, 2011; see also, e.g., Munda, 2015; Ameen and Mourshed, 2019; see also HDL, 2021) in the optimal sense:

1. A definition and set of evaluation criteria, which are clearly discriminating (i.e., indicators that measure distinctive qualitative dimensions) with minimal overlaps of criteria.
2. The design of an assessment system that assigns each element of a concept or strategy to one or more distinct evaluation criteria.
3. Evaluation scheme: A pre-defined transformation function assigning a certain qualitative or quantitative measurement unit to each realization of an element allowing an allocation of points depending on the achievement of objectives.
4. A weighting procedure of each dimension (if necessary): i.e., the question, whether all dimensions are weighed equally or need to be adjusted.
5. Final comprehensive evaluation: A mental, conceptual or computational model for the aggregation of the measurement units to a uniform metric or a comparable result.

With respect to 1., it is to be expected that this requirement will not fully be achievable. Cities are highly complex and interconnected systems and therefore, evaluation criteria will be just dependent respectively interconnected. For instance, the different dimensions of smart cities used below (smart people, smart government, smart environment, smart economy, smart living, smart mobility) are also not distinct respectively, not clearly discriminating.

Regarding 2., and 3., it can be assumed that these requirements can be fully met by the assessment criteria presented below.

A weighting procedure as per 4., is not considered purposeful in this work since all six dimensions are regarded as equally important for smart city concepts.

With respect to 5., a simple aggregation model will be used in this thesis.

As the objects of the evaluation pursued in this thesis are three selected smart city concepts, a further methodological step accounts for the criteria of selecting the appropriate cities for the analysis. For this step, the following section refers to the operational definition of “smart city” that was developed in chapter 2.6 for the research aim of this thesis. Taking this definition, a set

[11] Concepts and strategies may also be analyzed quantitatively by bibliometric or content analysis. Mattoni et al. (2020) present a quantitative multicriteria approach to the planning of a smart city.

of dimensions and indicators is developed that is based on the ISO 37120 indicator sets as well as Giffinger's et al. (2007), Boyd's (2014) and Sharifi's (2019) list of characteristics, factors and indicators.

3.3 Criteria for the selection of cities to be assessed in this thesis

Before turning to the evaluation criteria for the selected smart city concepts, the selection of cities functioning as case-studies should be discussed. While any selection criterion is somewhat arbitrary, it is necessary to make the selection process as clear and trackable as possible. In terms of a statistical analysis, one would aim for a sample of cities that are representative in regard to size, socio-economic characteristics, regional context, and location. However, as this thesis is concerned with an analysis of smart city strategies at a conceptual level, it focuses on an in-depth qualitative analysis based on a wide range of indicators (see chapter 3.4 below).

The following criteria will be used to select the three cities as case-studies for this thesis.

1. Selected cities should be cities that are known for being "smart", and that have drafted a smart city strategy or concept.

   While some cities might be "smart" without having an explicit smart city strategy, this thesis is concerned with the perception and acknowledgement of the smart city concept by the city administrations, planners and policy makers. In order to analyze the understanding of a smart city – as it is defined in the scientific literature –, cities with elaborated smart city strategies will be chosen. In regard to the availability of data and the strategies, the cities to be selected should also have a smart city strategy, i.e., a comprehensive document, and an implementation strategy available.

2. The cities selected should be European cities, in order to enable the comparison in a joint European context.

   For a comparison and assessment of smart city concepts in the framework of this thesis, the number of cities has to be limited. However, if cities are chosen that are very different in regard to the socio-economic characteristics, or from largely different regional (political/institutional) contexts, potential differences of smart city concepts may be attributable not only to the differences in the concepts per se, but also may be linked to the more significant differences of regional contexts. Therefore, this thesis is restricted to European cities with more similar institutional, economic and legal frameworks.[12]

[12] It is important to note that a top ranking of a certain city in international smart city assessments does not necessarily mean that a high rank of smartness is achieved, or that other cities that rank lower are

3. Chosen cities should be reasonably large or medium-sized cities.

   Although small cities or municipalities often have development concepts, they regularly have only a limited capacity of developing such strategies. Most often, smart city strategies are drafted by larger cities and agglomerations that (have to) deal with significant urban problems (e.g., pollution, migration, lack of social cohesion), and therefore also face a certain pressure to develop smart policy programs.

4. Cities should be included in the WCCD[13] (see Table 5) or in another widely accepted and officially published smart city ranking.

   In order to enable a comparison of cities, the cities should be ranked according to a common assessment method such as the ISO 37120 standards, or another comparable smart city ranking using similar indicators. Otherwise, differences and comparisons of smart city concepts cannot be reasonably differentiated between differences in content, and differences in the evaluation procedure (methodology).

5. The ranking of selected cities should mirror a certain variation (top/medium/low ranking) (see Table 6).

   Finally, the existing ranking of selected cities should mirror the variety of ranks in the assessment, i.e., that the cities selected for this thesis should not only be top-ranked. The assessments (rankings) should therefore be varied in order to ascertain whether the various rankings may be based on different smart city concepts.

6. The selected cities should be ranked in recent assessments.

   One of the first and comprehensive smart city assessments was done by Giffinger et al. (2007). However, the "smartness" of cities has rapidly evolved since this report, as cities have drafted numerous smart city strategies, and pursued and implemented smart policies. A city ranked low ten years ago might well have implemented smart city strategies since then. Therefore, the selection of cities should reasonably be decided based on

less smart. Especially from a developing country's perspective, some indictors of internationally applied assessment methods do not reflect the local problems adequately. For instance, some cities in the Global South struggle to provide their citizens with pure drinking water, sanitation, and flood control. Such fundamental services are not included in some of the rankings since cities in industrialized countries have usually solved such problems (see Backhouse and Zaber, 2020).

[13] The WCCD (World Council on City Data) is a global registry of cities that were subject to a smart city evaluation based on the ISO 37120:2014 or 2018 framework ("Sustainable cities and communities — Indicators for city services and quality of life / Indicators for Smart Cities / Indicators for Resilient Cities") (WCCD, 2020).

recent data in order to assess the most recent concepts in the course of the empirical work of this thesis.

By applying the selection criteria discussed above, the following European large to medium-sized cities are included in the WCCD ranking, or in other smart city rankings mentioned above:

Table 5: Certified assessments (included in the WCCD data base) of smart cities in the European Union based on the ISO 37120 frameworks

City[a]	Year of evaluation (latest available)	Level of certification[b]
Amsterdam (NL)	2015, 2016	Gold (=4)
Barcelona (ES)	2014	Platinum (=5)
London (UK)	2015	Platinum (=5)
Rotterdam (NL)	2014	Platinum (=5)
Valencia (ES)	2015	Platinum (=5)
Porto (PT)	2016, 2017	Gold (=4)
Koprivnica (HR)	2016	Platinum (=5)
Zagreb (HR)	2016	Platinum (=5)
Eindhoven (NL)	2016	Platinum (=5)
Heerlen (NL)	2016	Platinum (=5)
Gdynia (PL)	2018	Platinum (=5)
Aalter (BE)	2017, 2018	Platinum (=5)
Sintra (PT)	2017, 2018	Platinum (=5)
Zwolle (NL)	2017	Platinum (=5)
The Hague (NL)	2017, 2018	Platinum (=5)
Kielce (PL)	2017	Platinum (=5)
Warsaw (PL)	2018	Platinum (=5)

[a] For some cities in this list, the level of certification has significantly improved, for instance, for Amsterdam (NL) and Kielce (PL).

[b] The "level of achievement" displays the certification level (and not the smartness of a city); "aspirational" is the lowest standard (=1), "platinum" the highest (=5) on a five-point scale. The ranking is based on the number of criteria used in the smart city assessment (up to 104 indicators are used for the assessment based on the ISO 37120 framework). Only the highest levels of certification for each city are displayed.

Source: Own compilation based on WCCD (2020).

The WCCD collection of cities certified under the ISO 37120 frameworks is only one major database of smart cities ranked according to their smartness. As discussed in chapter 2 above, there are numerous approaches to defining and ranking (assessing) smart cities. Sharifi (2020 a) list 34 different assessment and evaluation schemes, which include tools, frameworks, indices and indicator sets. These schemes are diverse in regard to their geographical coverage, the characteristics/policy fields and indicators chosen, the availability of data, and the general depth, focus and refinement of the analysis.

There are, however, some rankings of smart cities that are focused on European cities (i.e., many cities in Europe have been assessed by these rankings), and are more recent (2019, 2020). The comparison of the two selected rankings (IESE, 2019; IMD, 2020) exhibits significant differences in the indicators and dimensions used, and the empirical ranking results. Table 6 presents the ranking of the two selected smart city assessments for the first 30 European cities.

Table 6: Recent international and comprehensive smart city assessments [a]

Ranking by								
IESE (2019)					IMD (2020)			
Rank	City	Country	Ranking out-come [b]	Points	Rank	City	Country	Ranking outcome
1	**London**	UK	H	100.00	2	Helsinki	FI	AA
3	Amsterdam	NL	RH	86.70	3	**Zurich**	CH	AA
4	Paris	FR	RH	86.23	5	Oslo	NO	AA
5	Reykjavík	IS	RH	85.35	6	Copenhagen	DK	AA
8	Copenhagen	DK	RH	81.80	7	Geneva	CH	AA
9	Berlin	DE	RH	80.88	9	Amsterdam	NL	A
10	**Vienna**	AT	RH	78.85	11	Munich	DE	A
13	Stockholm	SE	RH	77.89	13	Dusseldorf	DE	A
14	Oslo	NO	RH	77.45	15	**London**	UK	A
15	**Zurich**	CH	RH	76.66	16	Stockholm	SE	A
22	Helsinki	FI	RH	74.08	17	Manchester	UK	A
24	Madrid	ES	RH	73.02	22	Hamburg	DE	A
27	Munich	DE	RH	72.71	24	Bilbao	ES	BBB
28	Barcelona	ES	RH	72.25	25	**Vienna**	AT	BBB
29	Basle	CH	RH	70.39	28	The Hauge	NL	BBB
31	Bern	CH	RH	70.03	29	Rotterdam	NL	BBB
32	Geneva	CH	RH	69.78	31	Gothenburg	SE	BBB
33	Frankfurt	DE	RH	69.39	33	Hanover	DE	BBB
34	Hamburg	DE	RH	69.23	34	Dublin	IE	BBB
36	Göteborg	SE	RH	68.65	38	Berlin	DE	BBB
37	Dublin	IE	RH	68.19	40	Birmingham	UK	BBB
41	Milan	IT	RH	65.94	44	Prague	CZ	BB
43	Rotterdam	NL	RH	65.38	45	Madrid	ES	BB
44	Lisbon	PT	RH	65.32	48	Zaragoza	ES	BB
46	Edinburgh	UK	RH	65.06	49	Barcelona	ES	BB
47	Prague	CZ	RH	64.97	51	Lyon	FR	BB
48	Brussels	BE	RH	64.79	55	Warsaw	PL	B
50	Dusseldorf	DE	RH	64.34	56	Moscow	RU	B
51	Cologne	DE	RH	64.19	58	Krakow	PL	B
53	Stuttgart	DE	RH	64.01	59	Tallinn	EE	B

[a] Reduced to the best 30 European cities

[b] H = High; RH = Relatively high (the remaining ranking outcomes were Medium, Low and Very Low).

Note: Cities in bold letter are the cities selected for an in-depth analysis of this thesis.

Source: Own compilation based on IESE (2019) and IMD (2020).

For the IESE (2019) assessment and ranking, the following fields of evaluation were used:

- Human Capital,
- Social Cohesion,
- Economy,

- Public Management & Governance,
- Environment,
- Mobility & Transportation,
- Urban Planning,
- International Outreach, and
- Technology

In these fields, a total of 96 empirical indicators were used to measure the progress of cities on their path to becoming “smart”.

The IMD (2020) evaluation was based mainly on the technological provisions of each city in five fields:

- Health and safety,
- Mobility,
- Activities,
- Opportunities, and
- Governance

As Table 6 above infers, the cities that are top ranked are mostly the same cities, though the respective rank differs between the two assessments. Other less comprehensive assessments such as the smart city ranking by Roland Berger (2020) also place some of these cities in high positions. For instance, London and Vienna are evaluated excellently, as are the German cities of Hamburg and Munich in the German digital smart city ranking (Bitkom, 2020). Equally focused on the technology and digitization of cities is McKinsey’s smart city ranking, which again shows that London, Vienna, Amsterdam and other European cities are ranked very well (MGI, 2018). In MGI (2018), many fields such as health, governance, mobility are evaluated in regard to, e.g., mobile applications, E-governance, E-health or similar.

While the European Commission in their SMART initiative has clearly laid a focus on a comprehensive set of fields of assessments that are based on the United Nations Sustainable Development Goals (SDG) (see Borsboom-van Beurden et al., 2019), some of the rankings mentioned above (e.g., MGI, 2018; Bitkom, 2020) still evaluate cities with a narrow set of indicators of digitization and technologies. As discussed above in section 2, critics argue that a smart city is not necessarily a sustainable one, since the understanding of “smart” in a narrow technological meaning falls short of sustainable urban development as it is conceptualized, for instance, in the SDGs (see Yigitcanlar et al., 2019b).

As this brief discussion shows, the empirical rankings of cities in regard to their smartness focus on different fields and indicators. However, most cities ranked high in one assessment can also be found in other evaluations and rankings as well.

The choice for the empirical part of this thesis on the evaluation and assessment of smart city concepts can therefore be based on the cities included in these rankings. The three cities selected are:

- London,
- Vienna, and
- Zurich

London is the largest city in those selected for this thesis (8.9 million inhabitants), and is mostly top-ranked both in assessments that are narrowly focused on technology, and in those that consider various fields of sustainability as well. The city administration, planning and politics have designed numerous strategies, planning documents, and implementation strategies that provide a rich source of empirical (conceptual) information for this thesis. As will be shown by the evaluation below in section 4, the London smart city strategy is mainly focused on technology and digitization, and therefore serves as a prominent example of smart city strategies of this kind.

Vienna is the second-largest city in this small sample (1.9 million inhabitants), and earned various ranks (from top to medium ranks) in some of the assessments discussed above. In some other assessments, Vienna was also labeled as the most livable city by Mercer (2019). In regard to digitization, Vienna seems to be not in the group of the most advanced cities. Though, in regard to a broader conceptualization of smart cities that includes sustainability or SDG indicators as well, Vienna was chosen as a city to be studied in this thesis. As it will be discussed below, Vienna also has the single most comprehensive smart city strategy of all cities discussed so far.

Zurich (0.42 million inhabitants) has recently passed its smart city strategy in 2018, focusing on digital transformation of all areas of urban policies. However, Zurich has also an urban development strategy that refers to digitization in sub-chapter. Zurich may therefore be a city that has several strategy and policy documents that – taken together – form a comprehensive strategy for a smart development.

Having discussed the selection of cities to be studied empirically in this thesis, the final section below of this chapter on the methodology describes the fields and indicators used for assessing the three smart city strategies.

3.4 Research instrument: Evaluation and assessment criteria for smart city concepts

As discussed in section 2, there are numerous definitions and concepts for smart cities, and smart urban development. The technology-driven concepts on the one hand define smart cities mostly in terms of the use and dissemination of ICTs (information and communication technologies) as tools and instruments for urban development. However, critics (e.g., Yigitcanlar et al., 2019b) have argued that the concentration on technologies ignores the broader perspectives on sustainable urban development. From this viewpoint, ICTs are considered as tools and instruments for supporting and enabling a sustainable urban development. However, a smart city is therefore also a city that takes the full breadth of sustainable development (e.g., efficiency, sufficiency) into account. In its most broad version, a smart city is a city that designs its smart city strategies along the Sustainable Development Goals (SDGs) of the United Nations.

A clear own concept of smart cities is therefore necessary to assess and evaluate smart city concepts as the definitional foundation is also the underlying concept for criteria of assessments and evaluation. This thesis is concerned with the evaluation of smart city concepts, i.e., that the selected cities are not ranked according to their smartness – examples of such rankings are given in section 3.3 above. Rather, this thesis discusses the smart city concepts and strategies selected on the theoretical, methodological and conceptual level.

The understanding of a "strategy" forms an important part of the design of evaluation criteria. A strategy is commonly defined as "a plan that is intended to achieve a particular purpose" (Oxford Dictionary). A plan involves a certain aim or purpose that should be achieved, including a perspective on the time frame and the spatial outreach, and the instruments which are necessary to achieve the goals.

In order to assess/evaluate smart city concepts and strategies, this definition of 'strategy' will be followed. Taking the smart city definitions of Giffinger et al. (2007), Cohen (2014), Ibrahim (2018)., Yigitcanlar et al. (2019b) and Sharifi (2020), a framework of criteria (indicators) for assessing the smart city strategies selected was set up.

The assessment (evaluation) of the selected smart city strategies (concepts) will be pursued with two groups of criteria.

- Firstly, the strategies (concepts) will be assessed according to a number of *formal criteria*, such as the draft of a comprehensive strategy, the clear assignment of responsibility, or the consistency with ISO norms or the UN's Sustainable Development Goals (SDGs) (see Table 7).
- Secondly, the strategies will be assessed on the basis of the *content of the strategies*, described qualitatively, and evaluated on the basis of the quantitative indicators presented below in Table 8.

As mentioned above, there are quantitative assessment methods available that mostly rely on bibliometric analyses. However, for the conceptual assessment pursued in this thesis, a combination of a qualitative (verbal-hermeneutic) assessment, and a quantitative evaluation based on two realizations of indicators, can achieve the goals of research most appropriately.

The following two tables (Table 7 and Table 8) present the dimensions and indicator groups, and also briefly describe the method of assessment (evaluation) in the respective notes to the tables.

Table 7: Formal criteria (indicators) for the conceptual assessment and evaluation of smart city strategies in three selected cities (London, Vienna, Zurich)

Main formal criterion	Description and content of the formal criterion
Comprehensive smart city strategy	Strategy laid out in one document, or separate documents (e.g., for transport, ICT, participation)
Political/administrative responsibility	Shared or centralized responsibilities for the drafting and implementation of the smart city strategy
Contradicting urban strategies/policies	Implementation of other strategies or policies that contradict, or hinder, the smart city strategy; discussion of trade-offs and synergies
ISO-standards, European reference	Reference to ISO standards and frameworks (e.g., ISO 37120), and/or to specific European standards (e.g., European Commission)
Sustainable development goals (SDGs)	Design of criteria for evaluation/assessment in regard to SDGs

Note:
Evaluation of the criteria in two steps:
(1) *Description* and qualitative (verbal) assessment of each formal criterion;
(2) *Account* of the criteria on the basis of a three-point scale: 3=complete account of the criterion; 2=partial account; 1=unsatisfactory account.

Source: Own concept based on smart city definitions and indicators discussed in Giffinger et al. (2007), Cohen (2014), Ibrahim (2018)., Yigitcanlar et al. (2019b), Sharifi (2020).

Table 8: Criteria (indicators) of the contents for the conceptual assessment and evaluation of smart city strategies in three selected cities (London, Vienna, Zurich)

Dimension of smart city strategy	Fields of dimensions	Concrete groups of indicators
Smart Environment & Use of Natural Resources	Sustainable resource management and pollution	Carbon footprint (production & consumption)
		Air quality, noise pollution
		Waste generation and treatment
		Water/waste water
	Sustainable urban planning and development	Energy and climate related planning (mitigation & adaptation)
		Public spaces, green and blue infrastructure
	Smart buildings	Building codes, certified buildings, smart homes
Smart Mobility	Sustainable, innovative and safe transport systems, clean-energy transport	Public transport, bikes, pedestrians
		Motorized private transport
		Freight transport
		Local, regional, international accessibility
	Sustainable transport policies	Taxation, permit systems, restrictions
	Sharing systems	Car/bike sharing
	Technological infrastructure	Smart information systems, smart cards, real-time information
Smart Economy & Competitiveness	Innovation, Research & Development (R&D)	Knowledge-based economy
		Research institutions, innovativity
	Entrepreneurship	Start-ups, employment growth
	Production/income, productivity	Level and rate of changes of local/regional GDP
	Competitiveness	Ratio of exports, types of exported goods
	Labor market institutions / flexibility	Economic perspectives on the labor market and its institutions/regulations
Smart People, Social & Human Capital	Social and ethnic plurality & diversity	(Change of) Demography of the population
	Education, qualification	Institutions, levels and rates of change of education/qualification
	Social cohesion, poverty, homelessness	Distribution of income, growth, social promotion
	ICT inclusion	Connectedness & use of ICT by citizens
	Social capital	Levels of participation, civic engagement, urban living labs
Smart Government	Participation in decision-making	Participation, E-governance
	Public and social services	Quality of public services, contribution to sustainable urban development
	Transparent / open governance & government	Open data, apps, privacy, E-government
Smart Living & Quality of Living	Public health	Livable city ranking, quality of life, life expectancy
	Housing	Social housing, levels of rents, real-estate prices
	Safety & security	Crime, prevention & levels
	Culture & well-being	Attendance, cultural spending (private, public, corporate)
Extent of ICTs	ICT as enabling/supporting infrastructure	
	ICT as central element in order to increase efficiency	

Note:
Evaluation of the criteria in two steps:
(1) *Description* and *qualitative (verbal) assessment* of each formal criterion;(2) *Account of the criteria* on the basis of a three-point scale: 3=complete account of the criterion; 2=partial account; 1=unsatisfactory account; n.a.=criterion not available for assessment (i.e., not included in the strategy analyzed);

Source: Own concept based on smart city definitions and indicators discussed in Giffinger et al. (2007), Cohen (2014), Ibrahim (2018)., Yigitcanlar et al. (2019b), Sharifi (2020).

The evaluation of the concepts on the basis of Table 7 and Table 8 is carried out in iterative steps. First, the concepts are critically reviewed several times and an initial qualitative brief description is written. Then, the criteria are applied and used to evaluate the concepts. For the evaluation, a keyword search is performed based on the criteria. Thus, the concepts are analyzed qualitatively hermeneutically and the indicator values are assigned from the frequency and the level of detail of the concepts and their contexts.

However, this approach is necessarily subjective, but it is made as comprehensible as possible to readers through transparent discussion. This kind of method is often found in content analysis, where the treatment of certain topics and contexts is judged by the depth of the use of these terms.

Of course, it cannot be ruled out that there is a bias of the researcher here, this is certainly a clear limitation of the study. However, the maximum attempt is made to make all evaluations (qualitative textual and based on the selected indicators) as transparent and comprehensible as possible.

Many sources of bias can undermine the validity of findings (see, for example, Onwuegbuzie and Leech, 2007 and Norris, 1997). Onwuegbuzie and Leech (2007) list 24 different dimensions to assess the validity of qualitative research findings. To address these potential concerns, this paper follows a structured approach that begins with a description and analysis of theoretical smart city concepts, followed by the design of an own operational smart city definition. Based on these considerations, an evaluation methodology is developed in the section above. Furthermore, a clear and transparent process for selecting case study cities is presented. Despite this transparent process, it cannot be excluded that there is a bias in the qualitative interpretation and evaluation. This could have been investigated, for example, through supplementary expert interviews or other further literature sources, but this would have been beyond the scope of this thesis.

4 RESULTS AND DISCUSSION

4.1 Introduction

In the following chapter, the smart city concepts of London, Vienna and Zurich are analyzed and assessed as presented in chapter 3 (Methodology). The smart city strategies are discussed based on the smart city concept developed and presented in chapter 2.6, and evaluated and compared using the criteria and indicators defined in chapter 3.

The structure of this chapter is as follows: Section 4.2 provides a descriptive overview of the contents of each smart city concept. It should be noted that each city has designed and implemented a smart city concept. However, these concepts are not the only concepts for urban policies and planning. Each city has numerous other planning or policy-related concepts and strategies as well as urban development plans in addition to the actual smart city concepts. London and Zurich, in particular, explicitly refer to these concepts in their smart city strategies. The focus of this paper and the assessment outlined above, however, is on comparing and understanding the explicit *concept of smart city* in each selected city. Reference to other underlying strategy and policy plans is made only when necessary. From this viewpoint, the following analysis evaluates the smart city strategies of the three selected cities in regard to their reference to the definition developed above and the indicators that have followed from this operational definition.

4.2 Description of concepts

The following sections 4.2.1 to 4.2.3 describe the smart city concepts of each city being subject to this thesis: London, Vienna and Zurich. As the analysis will show, the concepts of these three cities are extremely different - particularly in regard to the overarching goals and their sub-goals, their depth of contents, the issues addressed, and the underlying framework strategies, contracts, or agreements.

Nevertheless, to facilitate the overview, the concepts are summarized in tables and the contents of the concepts were color-coded. Overarching goals in terms of e.g., dimensions or mission statements are highlighted in yellow, secondary or subordinate content-related goals or topics are highlighted in red, and specific topic areas are highlighted in purple.

As can be clearly seen below, the qualitative description of the smart city concepts for the individual cities varies in scope. This is due to the fact that the concepts differ significantly in both, scope and depth of content. Vienna has by far the most comprehensive concept, which also most closely matches the operational definition proposed above in section 2.6. London is entirely technocentric, focusing on individual and mostly unrelated technical projects. London's smart city concept is disconnected from existing urban development concepts. Zurich has a very concise concept, but one that relates to individual smart city dimensions. It is therefore not surprising that the description based on the preselected criteria and analysis steps also varies in intensity.

4.2.1 London[14]

London's "Smarter London Together – The Mayor's roadmap to transform London into the smartest city in the world" (Greater London Authority, 2018) (SLT) is a non-legislative strategy document of the mayor of London. The SLT is an update of previous strategy papers, such as the Smart London Plan 2013 and Smart London Plan 2016, and serves as a supporting instrument for the following "Mayoral strategies" (p. 8):

- Transport,
- Environment,
- Health inequalities,
- Housing,
- Culture,
- Economic development, and the
- London Plan.

The understanding of the smart city notion according to the SLT strategy is: "A smart city is a collaborative, connected and responsive city. It integrates digital technologies and uses city-wide data to respond to our citizen's needs (Greater London Authority, 2018, p. 6). The SLT serves as a strategy document in order to provide "better digital services, open data, connectivity, digital inclusion, cyber-security, innovation, and City Hall's plan for the growth of our city to more than 11 million residents by 2050" (Greater London Authority, 2018, p. 6).

Thus, London has a clearly tech-driven smart city concept focusing on five "missions" laid out in Table 9 below.

[14] The entire chapter 4.2.2 is based on information compiled from Greater London Authority, 2018, unless stated otherwise.

TABLE 9: LONDON'S SMART CITY MISSIONS ACCORDING TO "SMARTER LONDON TOGETHER"

Transformation of London into the smartest city in the world	
Mission 1: More user-designed services	• Leadership in **design and common standards** to put users at the heart of what we do • Develop new approaches to **digital inclusion** to support Londoners' access to public services • Launch the Civic Innovation Challenge to **spur innovation** from the tech sector • Explore new civic **platforms to engage citizens** and communities better • Promote more **diversity in tech** to address inequality
Mission 2: Strike a new deal for city data	• Launch the London Office for Data Analytics (LODA) programme to increase **data sharing** and collaboration for the benefit of Londoners • Develop a city-wide **cyber security strategy** to coordinate responses to cyber-threats to businesses, public services and citizens • Strengthen **data rights and accountability** to build trust in how public data is used • Support an open ecosystem to **increase transparency** and innovation
Mission 3: World-class connectivity and smarter streets	• Launch a new Connected London programme to **coordinate connectivity and 5G projects** • Consider planning powers, like requiring **full fibre** to the home for all new developments, to enhance connectivity in the future • Enhance **public wifi** in streets and public buildings to assist those who live, work and visit London • Support a new generation of **smart infrastructure** through major combined procurements •Promote **common standards** with smart tech to maximise benefits
Mission 4: Enhance digital leadership and skills	• Enhance **digital and data leadership** to make public services more open to innovation • Develop **workforce digital capability** through the Mayor's Skills for Londoners Strategy • **Support computing skills** and the digital talent pipeline from early years onwards • Recognise the role of **cultural institutions engaging citizens in the digital world**
Mission 5: Improve city-wide collaboration	• Establish a London Office of Technology & Innovation (LOTI) to **support common capabilities and standards for future innovation** • Promote **MedTech innovation in the NHS** and social care to improve treatment • Explore **new partnerships with the tech sector** and business models • Support **better Greater London Authority (GLA) Group's digital delivery** to improve effectiveness • **Collaborate with other cities in the UK and globally** to adopt and share what works

Source: Adapted from Greater London Authority (2018, p. 5), author's draft.

Further, Appendix 2 (Greater London Authority, 2018, p. 46ff) briefly refers to specific ongoing urban projects "using data and technology to make a difference" (p. 46). These project's content references are: air quality, collaboration with startups and small and mid-sized enterprises (SMEs), avoiding crowds in the London underground, planning and urban design (enhance and increase 3D virtual reality), data usage for infrastructure planning, data usage for tackling fuel poverty, data usage for mapping and benchmarking cultural venues, data usage for tackling crowd levels at night, and improving access to education and improving - inter alia - digital skills.

The above chapter summarizes London's approach towards smartness. Apparently, the SLT strongly focuses on tech- and data-driven measures by listing five main missions and their corresponding sub-goals. The latter will be analyzed in chapter 4.3 in much more detail on the basis of the evaluation formal and content indicators developed in section 3.4.

4.2.2 Vienna[15]

Vienna's "Smart City Wien Framework Strategy 2019 – 2050, Vienna's Strategy for Sustainable Development" (SCWFS) was adopted by the Vienna City Council on June 26th, 2019 and was published in December 2019. Therefore, it is a binding strategy document. The SCWFS represents an update of the original Smart City Wien Framework from 2014.

Vienna's understanding of being a smart city is as follows: "Vienna is a city that is constantly able to reinvent itself and develop innovative solutions to enable sustainable future development; and at the same time a city that remains true in its basic values, attaching the same importance to social inclusion and quality of life for everyone who lives here as it does to the climate and environment objectives. Vienna's definition of smart means amalgamating innovations and new technological and digital capabilities, climate action and resource conservation, high social standards and opportunities into an overall vision that inspires people and prompts desire for change" (City of Vienna, 2019, p. 7).

Vienna's SCWFS is embedded in a framework of national and international agreements and targets such as

- "The Sustainable Development Agenda" by the United Nations including the 17 Sustainable Development Goals.
- The "Paris Agreement on Climate Action" aiming to keeping global warming below 2°C above pre-industrial levels.
- EU-wide targets and policy objectives defined by the "2030 climate and energy framework" (as a part of the 2018 "Clean Energy for All Europeans" package) aiming at a minimum reduction of 40% in greenhouse gas emissions (based on 1990 levels), a minimum 32% share for renewable energy, and a minimum of 32.5% improvement in energy efficiency (European Commission, 2021b).
- The "EU Circular Economy Action Plan" fostering the transition towards a circular economy by a variety of measures such as fostering sustainable products, empower

[15] The entire chapter 4.2.2 is based on information compiled from City of Vienna, 2019, unless stated otherwise.

consumers, focusing on resource-intensive sectors and products (e.g., ICT-devices, batteries and vehicles, packaging, construction and buildings) (European Commission, 2021c).

- The “National Energy and Climate Plan for Austria” aiming at a 36% CO_2 reduction by 2030 compared to 2005 being in line with the EU targets.
- The “mission 2030” targeting 100% renewable electricity by 2030 for Austria.

Using the above-mentioned agreements and strategy papers as a basis, Vienna regards its SCWFS as a local response to global issues such as growing cities (by which Vienna is also strongly affected), rapid developments in digitalization and technologies, and resource consumption exceeding planetary boundaries. Nevertheless, Vienna takes a critical view of the use of technology and emphasizes that the use of new technologies and digitalization must always focus on people – in the sense of solving or alleviating urban problems, increasing public participation and making life more comfortable.

Further, the SCWFS is committed to achieving a strong level of resilience by combining public safety, civil protection and disaster management with innovation, digitalization, education, health services as well as ecological topics and climate action. The SCWFS serves as an “umbrella strategy” by bringing together a “high quality of life, social inclusion, maximum conservation of resources and extensive capacity for innovation” (City of Vienna, 2019, p. 21).

Another major foundation of the SCWFS is the reference to the UN 2030 Agenda for Sustainable Development. The SCWFS is not only committed to the UN Sustainable Development Goals (as mentioned already at the beginning of this section), but is also to be understood as a strategy document to fulfill and implement the UN 2030 Agenda. An explicit reference to the preamble of the 2030 Agenda is included in the SCWFS, explaining the necessity of incorporating the 17 SDGs into the SCWFS: “We recognize that social and economic development depends on the sustainable management of our planet’s natural resources. […]. Sustainable development recognizes that eradicating poverty in all its forms and dimensions, combatting inequality within and among countries, preserving the planet, creating sustained, inclusive and sustainable economic growth and fostering social inclusion are linked to each other and are interdependent. We recognize that sustainable urban development and management are crucial to the quality of life of our people” (City of Vienna, 2019, p. 23).

In anticipation of the following analysis, it should be noted at this point that Vienna fulfills the fundamental requirement of integrating the concept of sustainability - as demanded, for example, by scholars such as Yigitcanlar et al. (2019b) – insofar as the strategy paper builds on the 17 UN Sustainable Development Goals.

In its mission statement, Vienna’s SCWFS outlines three dimensions of smartness, each being interlinked with the respective others:

- Quality of live,
- Innovation, and
- Resources.

The summary version reads: "High quality of life for everyone in Vienna through social and technical innovation in all areas, while maximizing conservation of resources". In this context, explicit reference is also made to the need of not losing sight of the "Human scale" by placing the "focus on the needs of local people" (City of Vienna, 2019, p. 29).

The mission statement is the umbrella for 12 thematic fields, and these in turn are divided into 65 individual objectives – depicted in the following Table 10.

Table 10: Vienna's smart city dimensions, headline goals and thematic fields according to the SCWFS

The Three Dimensions		
Quality of life	**Resource conservation**	**Innovation**
	The Headline Goals	
• Vienna is the city with **the highest quality of life** and **life satisfaction** in the world. • Vienna focuses on **social inclusion** in its policy design and administrative activities.	• Vienna reduces its local per capita **greenhouse gas emissions** by 50 per cent by 2030, and by 85 per cent by 2050 (compared to the baseline year of 2050). • Vienna reduces its local per capita **final energy consumption** by 30 per cent by 2030, and by 50 per cent by 2050 (compared to the baseline year of 2005). • Vienna reduces its **material footprint of consumption** per capita by 30 per cent by 2030, and by 50 per cent by 2050.	• By 2030 Vienna is an **innovation leader**. • Vienna is Europe's **digitalisation capital**.
	Thematic Fields	
Energy supply	Water and waste management	Education
Buildings	Environment	Science and research
Mobility and transport	Healthcare	Digitalisation
Economy and employment	Social inclusion	Participation

Source: City of Vienna (2019, p. 34), author's draft.

This chapter is a compact summary of the underlying principles and agreements, the structure and the central objectives respectively topic areas of the of the Smart City Wien Framework Strategy. The content behind each Headline Goal and Thematic Fields, respectively, will be discussed in the detailed analysis in chapter 4.3.

4.2.3 Zurich

The Zurich smart city strategy paper comprises two documents[16]:

- “Strategies Zurich 2035” (SZ 2035) (Zurich City Council, 2016), and
- “Strategy Smart City Zurich” (SSCZ) (Zurich City Council, 2018).

The SZ 2035 addresses, as an umbrella strategy paper, the central challenges of the city in eight different fields ((1) attractive business location, (2) stable public finances, (3) sustainable growth, (4) solidary society, (5) sustainable energy and protection of the environment, (6) digital city, (7) cooperative representation of interests, (8) internal organization). These eight fields are summarized within “Three Main Questions” and their corresponding “Strategic Objectives”.

The following Table 11 summarizes the main contents of the Strategies Zurich 2035 accordingly.

[16] Unlike London's concept, it is clear from these two above mentioned documents that they belong together. For this reason, in the case of Zurich, an additional document is included in the analysis despite the requirement to use only the smart city strategy in each case.

Table 11: Main questions and strategic objectives of Strategies Zurich 2035

Main Questions		
What will we live on today and tomorrow?	**How do we maintain our quality of life?**	**How do we organize ourselves?**
	Strategic Objectives	
• Zurich is among the **leading business locations** in the world and offers attractive conditions for companies to operate in. • Zurich is a business location that features a **diversified industrial structure**. • Zurich is a business location that is home to a **skilled workforce**. • The City of Zurich's **public finances** enjoy long-term stability.	• All municipal activities take a **long-term perspective**. • Constructional densification is approached in a **socially responsible and ecologically compatible** way. • Zurich has a wide range of **housing** to offer to a diverse population. • Additional demand for mobility is to be satisfied with **public transport, pedestrian and bicycle traffic**. • Zurich offers **safety** and **solidarity**. • All municipal activities are aligned to the city's **social diversity**. • Zurich fosters prospects and opportunities for **teenagers and young adults**. • Zurich supports the health and **quality of life** of the population. • Zurich's **cultural program** offers diversity, quality and contemporary relevance. • The city's environmental and energy policy is guided by **true-cost pricing** and the "polluter-pays" principle. • Settlement development also takes into account local **renewable energy** potential. • The City of Zurich is well on the way to becoming a **2000-Watt Society**. • Zurich has a reliable and easily accessible **digital infrastructure**. • Services provided by the City and **participation processes** are supported **digitally**. • Zurich is one of the world's top locations for **ICT services**.	• The interests of the City of Zurich are represented **effectively**. • The **regional context** is consistently taken into account and included. • Specific city-related costs will be **appropriately reimbursed**. • **Municipal services** meet regulatory requirements which are modified by society and its organization. • The **administration's structures and processes** are as closely aligned as possible to its responsibilities. • The City of Zurich is an **attractive employer**.

Source: Adapted from Zurich City Council (2016, p. 5 ff), author's draft.

The second document – Strategy Smart City Zurich (SSCZ) (Zurich City Council, 2018) – complements the first document described above with the claim to deal specifically with the smart city notion. Its purpose is to foster "the implementation of the 'Zurich Strategies 2035' and of a number of specific strategies" (Zurich City Council, 2018, p. 5). Zurich's definition of "smart" is as follows: "'Smart' means connecting people, organisations or infrastructures in such a way as to create social, ecological or economic added value" (Zurich City Council, 2018, p. 6). SSCZ lists several "purposes" and "focus areas" (p. 8 ff) of Smart City Zurich – the respective summary is presented in Table 12.

Table 12: Purposes and focus areas of Smart City Zurich

Purposes of Smart City Zurich	
Focus on the needs of the target groups and the challenges facing the city:	Smart City Zurich is aligned to the city's long-term goals. New technological solutions are being adopted to help meet urban challenges. A user-oriented development as well as a focus on people's needs are at the heart of this effort.
Networking and cooperation of people, organisations, infrastructures:	Smart City Zurich promotes internal and external collaboration across the boundaries of the organisation's units and departments as well as between the city administration, the population, business, science and culture. This approach also places an emphasis on digital options for public participation and infrastructure sharing.
Availability, self-determination and privacy with respect to data:	Smart City Zurich promotes internal and external collaboration across the boundaries of the organisation's units and departments as well as between the city administration, the population, business, science and culture. This approach also places an emphasis on digital options for public participation and infrastructure sharing.
Innovation and agile developments:	Smart City Zurich gives the city greater agility in the face of accelerated technological change. Innovative approaches are developed in experimental open spaces and tested in pilot projects or living labs. This is an approach that allows promising solutions to be identified and implemented early on.
Focus Areas of Smart City Zurich	
Future forms of integrated public mobility:	Social and technical trends such as the sharing economy, individualization, multimodality, digital booking platforms, electric mobility and autonomous driving are already changing the mobility market today. The City of Zurich is seeking to expand its range of public mobility services in a resource-friendly manner, allowing users to also experience them during trial operations: by replacing diesel buses with trolleybuses or e-buses, by setting up a mobility platform for the Zurich urban region, by conducting a pilot trial of demand-driven transport options and by carrying out tests in the area of autonomous driving.
Digital City:	The City Council wants to step up the digitization process in the city administration for the benefit of the population and businesses. This includes the expansion of the city's online portal, "My account", and the development of new online services, e.g., in the area of tax. The further modernization of the digital infrastructure in schools is ongoing. Internal administrative processes are being optimized and consistently digitalized, and technologies such as the Internet of Things are being used citywide.
Smart Participation:	Specific urban projects are used to test innovative forms of participation and the involvement of various stakeholders, with subsequent evaluation. "Smart Participation" connects the aspiration for participation by the population and stakeholders with the challenges of urban growth and technological change. Solutions that prove successful will be rolled out citywide. One of the first such projects is the process of reviewing the city/neighbourhoods interface, involving the use of eParticipation.

Source: Adapted from Zurich City Council (2018, p. 8 ff), author's draft.

This chapter is a compact summary of Zurich's approach towards the smart city notion. The comparative analysis will be given in section 4.3. Nevertheless, with regard to chapter 2.6 and its operational definition of a smart city concept, it is immediately apparent that Zurich does not refer to national or international treaties or strategy papers, let alone to an explicit sustainability concept such as the UN Sustainable Development Goals.

4.3 Detailed analysis

In continuation of chapter 4.2, which summarizes the individual smart city concepts of London, Vienna and Zurich verbally and hermeneutically, the present section evaluates the individual concepts with reference to chapter 3.4 on the basis of a conceptual comparison. This assessment provides an abstract analysis of whether the respective smart city concepts of London, Vienna and Zurich include the dimensions of the smart city concepts laid out in the scientific literature. As mentioned before, the operational definition of a smart city, and the indicators for the formal and content analysis provide the foundation of this section.

As such, this comparative approach is detailed on the basis of two sets of criteria (indicators). First, the fulfillment of *formal criteria* (such as e.g., the design of a comprehensive strategy, the clear assignment of responsibility, or the compliance with ISO standards or the UN Sustainable Development Goals (SDGs)) is assessed (chapter 4.3.1). In the second step, the strategies are evaluated in *terms of content*, described qualitatively and assessed using the quantitative indicators discussed above (chapter 4.3.2). For further more detailed reference see chapter 3, Methodology.

The documents assessed in this chapter are:

- “Smarter London Together – The Mayor’s roadmap to transform London into the smartest city in the world” (SLT) (Greater London Authority, 2018),
- “Smart City Wien Framework Strategy 2019 – 2050, Vienna’s Strategy for Sustainable Development” (SCWFS) (City of Vienna, 2019),
- “Strategies Zurich 2035” (SZ 2035) (Zurich City Council, 2016), and
- “Strategy Smart City Zurich” (SSCZ) (Zurich City Council, 2018).

4.3.1 Assessment of conceptual formal criteria

The evaluation of the formal criteria is done in two steps: Firstly, each formal criterion is verbally described and assessed. Secondly, each formal criterion is evaluated on the basis of a three-point scale: 3=complete account of the criterion; 2=partial account; 1=unsatisfactory account.

However, for the sake of clarity, the table with the evaluation results is given in the following text prior to the verbal discussion of the contents (Table 13).

TABLE 13: EVALUATION OF THE SELECTED SMART CITY CONCEPTS (LONDON, VIENNA, ZURICH) BASED ON FORMAL CRITERIA

Main formal criterion	Description and content of the formal criterion	London	Vienna	Zurich
(1) Comprehensive smart city strategy	Strategy laid out in one document, or separate documents (e.g., for transport, ICT, participation)	1	3	2
(2) Political/administrative responsibility	Shared or centralized responsibilities for the drafting and implementation of the smart city strategy	3	3	3
(3) Contradicting urban strategies/policies	Implementation of other strategies or policies that contradict, or hinder, the smart city strategy; discussion of trade-offs and synergies	1	1	1
(4) ISO-standards, European reference	Reference to ISO standards and frameworks (e.g., ISO 37120), and/or to specific European standards (e.g., European Commission)	1	3	1
(5) Sustainable development goals (SDGs)	Design of criteria for evaluation/assessment in regard to SDGs	1	3	1
	Total points:	**7**	**13**	**8**

Source: Own evaluation based on the indicators detailed in Table 7.

(1) Comprehensive smart city strategy: The smart city concept of London ("Smarter London Together", SLT) is a separate and complete document and also contains a number of policy goals. SLT refers in one paragraph to the existence of other urban strategies, but at no other point does the document address a link to these strategies mentioned. The London Concept is therefore rated with the indicator value of 1, as it is exclusively about the formulation and implementation of technology-centered goals, and therefore cannot be regarded as a comprehensive smart city strategy in the sense of this thesis. Vienna's smart city strategy (Smart City Wien Framework Strategy 2019 – 2050, Vienna's Strategy for Sustainable Development" (SCWFS)) is rated with an indicator value of 3 as it is a fully comprehensive and stand-alone strategic document, covering a complete range of urban topics and following the most comprehensive definition of a smart city ("energy supply, buildings, mobility and transport, economy and employment, water and waste management, environment, healthcare, social inclusion, education, science and research, digitalization, participation"; City of Vienna, 2019, p. 34). Zurich has as well a smart city concept ("Strategy Smart City Zurich" (SSCZ), although this concept clearly refers to a superordinate document ("Strategies Zurich 2035", SZ 2035). It is therefore rated with an indicator value of 2 as SSCZ is not a fully stand-alone and comprehensive document. Its focus areas are also techno-centric by addressing public mobility, digital city and smart participation (Zurich City Council, 2018). Further urban issues are addressed in SZ 2035 being not addressed under the smart city notion.

(2) Political/administrative responsibility: All three cities being subject to this assessment are rated with an indicator value of 3 as each city has a clearly defined administrative and political responsibility for the respective smart city concept. In the case of London, the Mayor and the Chief Digital Officer are responsible for the content and implementation of SLT (Greater London Authority, 2018). Vienna's SCWFS has been adopted by the Vienna City Council. The persons responsible for the implementation are the Mayor and the Executive City Councilor for Innovation, Urban Planning and Mobility, i.e. the municipal administration (Stadt Wien, 2021). Zurich's responsible body for its smart city strategy is the Zurich City Council (Zurich City Council, 2018).

(3) Contradicting urban strategies/policies: As laid out in chapter 2.5.8 it is questionable whether economic activities, especially in terms of economic growth, can fully take place while at the same time reducing the environmental impacts. This also concerns the issues of socially just distribution, sustainability and resource consumption. None of the smart city concepts examined meet the goal of remaining consistent - in the sense of offering no contradictions across all objectives. Furthermore, the concepts do not explicitly address potential contradictions nor offer a strategy to solve them such as a discussion of e.g., potential trade-offs. Therefore, all concepts are rated with an indicator value of 1.

(4) ISO-standards, European reference: None of the concepts assessed offer a reference to ISO standards and frameworks. In London's and Zurich's concepts no reference is given to any kind of generally acknowledged standards, nor to superior national or international goals or strategies. This circumstance complicates the measurability of the goals for the respective city, as well as the comparability of the goals of different concepts. Therefore, London and Zurich are rated with an indicator value of 1. Vienna, on the other hand, also has no reference to ISO standards as well, but cites a wide range of national and international policy documents and agreements. The intention for a holistic coverage of the smart city topic by referring to national and international standards is thus clearly recognizable. Therefore, Vienna's smart city concept is rated with a value of 3.

(5) Sustainable development goals (SDGs): Again, London and Zurich do not account for any reference to the UN's SDGs. Therefore, both smart city concepts are rated with 1. Vienna however, uses the 17 SDGs as its main reference. This is made clear by listing of the SDGs at the very beginning of the concept and the continuous reference to the individual SDGs in each individual chapter. Each chapter within the "Thematic Fields" begins with a reference to the SDGs affected by the topic.

The above section has investigated the underlying formal criteria of each smart city concept. In the following chapter, the focus is on the concept's respective content analysis.

4.3.2 Assessment of conceptual strategy content

TABLE 14: CRITERIA (INDICATORS) OF THE CONTENTS FOR THE CONCEPTUAL ASSESSMENT AND EVALUATION OF SMART CITY STRATEGIES IN THREE SELECTED CITIES (LONDON, VIENNA, ZURICH)

Dimensions	Fields of dimensions	Concrete groups of indicators	London	Vienna	Zurich
Smart Environment & Use of Natural Resources	Sustainable resource management and pollution	Carbon footprint (production & consumption)	1	3	1
		Air quality, noise pollution	2	3	1
		Waste generation and treatment	n.a.	3	n.a.
		Water/waste water	n.a.	3	n.a.
	Sustainable urban planning and development	Energy and climate related planning (mitigation & adaptation)	n.a.	3	1
		Public spaces, green and blue infrastructure	n.a.	3	1
	Smart buildings	Building codes, certified buildings, smart homes	n.a.	3	1
Smart Mobility	Sustainable, innovative and safe transport systems, clean-energy transport	Public transport, bikes, pedestrians	n.a.	3	1
		Motorized private transport	n.a.	3	1
		Freight transport	n.a.	3	n.a.
		Local, regional, international accessibility	n.a.	2	n.a.
	Sustainable transport policies	Taxation, permit systems, restrictions	n.a.	1	n.a.
	Sharing systems	Car/bike sharing	n.a.	3	n.a.
	Technological infrastructure	Smart information systems, smart cards, real-time information	3	n.a.	n.a.
Smart Economy & Competitiveness	Innovation, Research & Development (R&D)	Knowledge-based economy	3	3	1
		Research institutions, innovativity	3	3	1
	Entrepreneurship	Start-ups, employment growth	3	3	1
	Production/income, productivity	Level and rate of changes of local/regional GDP	n.a.	3	n.a.
	Competitiveness	Ratio of exports, types of exported goods	n.a.	1	n.a.
	Labor market institutions / flexibility	Economic perspectives on the labor market and its institutions/regulations	n.a.	3	1
Smart People, Social & Human Capital	Social and ethnic plurality & diversity	(Change of) Demography of the population	2	3	3
	Education, qualification	Institutions, levels and rates of change of education/qualification	1	3	2
	Social cohesion, poverty, homelessness	Distribution of income, growth, social promotion	1	3	n.a.
	ICT inclusion	Connectedness & use of ICT by citizens	3	3	1
	Social capital	Levels of participation, civic engagement, urban living labs	3	3	1
Smart Government	Participation in decision-making	Participation, E-governance	3	3	3
	Public and social services	Quality of public services, contribution to sustainable urban development	3	3	2
	Transparent / open governance & government	Open data, apps, privacy, E-government	3	3	3
Smart Living & Quality of Living	Public health	Livable city ranking, quality of life, life expectancy	2	3	3
	Housing	Social housing, levels of rents, real-estate prices	n.a.	3	2
	Safety & security	Crime, prevention & levels	1	3	2
	Culture & well-being	Attendance, cultural spending (private, public, corporate)	1	3	3
Extent of ICTs	ICT as enabling/supporting infrastructure		3	3	2
	ICT as central element in order to increase efficiency		3	1	1
		Total points:	44	92	39

Note:
Evaluation of the criteria in two steps:
(1) *Description* and *qualitative (verbal) assessment* of each formal criterion;(2) *Account of the criteria* on the basis of a three-point scale: 3=complete account of the criterion; 2=partial account; 1=unsatisfactory account; n.a.=criterion not available for assessment (i.e., not included in the strategy analyzed);

Source: Own evaluation based on Table 8.

Smart Environment & Use of Natural Resources

London: The smart city strategy of London only marginally refers to the dimensions of smart environment and use of natural resources. Many fields and the majority of indicators are not detailed or are not even mentioned in the smart city strategy. Most often, the criterion of improving air quality is referred to in the context of using air quality sensors and monitoring, collection of data, and clean production technologies. The strategy aims to "combat the causes and effects of pollution and climate change" (Greater London Authority, 2018, p. 10), but does not go into any detail how new technologies or data will be used to improve air quality. The importance of urban planning (e.g., smart buildings, sustainable urban planning by means of building codes) is not included in the strategy. The strategy stresses the importance of data networks, sensors, and clean technologies. If at all, the indicators are mentioned as examples without policy objectives, time lines, or instruments.

Vienna: Vienna's smart city strategy clearly tackles the issue of reducing the carbon footprint. The reduction of carbon emissions is declared as a primary target in the sections on mobility and transport, buildings, economy and employment, healthcare and governance. Several objectives are listed within each section, e.g., a shift to more efficient modes of transport, the increase of the share of carbon-free propulsion systems, the increase of material efficiency[17] by 30% by 2030, the preservation of unsealed surfaces, the efficient urban expansion and climate budgeting[18]. The reduction and minimization of air, water and soil pollutants as well as noise, heat and light reduction are explicit objectives within the sections on environment, and mobility and transport. Waste generation and treatment as well as water/waste water are clearly mentioned in a separate chapter as well as in numerous other contexts and backed up with clear objectives (e.g., waste prevention, recycling, increase of waste heat as part of the renewable energies, waste-free production processes, reduction of waste in the context of circular economy, maintaining the high quality of drinking water and waste water separation). Energy and climate related planning is subject throughout the whole SCWFS. However, this issue is also explicitly mentioned and backed up with goals such as doubling renewable energy production until 2030,

[17] "Material Efficiency" is defined in the SCWSF "as the gross regional product divided by regional material consumption" (City of Vienna, 2019, p. 87).
[18] „Climate Budgeting" is defined as „ a form of budgeting which shows the climate policy effect of each measure or cost position in the public budget (or parts thereof), usually in terms of the carbon emissions saved" (City of Vienna, 2019, p. 144).

making use of climatic advantages and natural daylight of construction sites, using construction materials from renewable sources, listing relevant specifications in public tenders or making use of digital building information modelling tools. Green and blue infrastructure is listed as an objective with regards to climate change and necessary cooling effects/avoidance of heat islands. Open spaces in general are a topic throughout the strategy and subject to numerous objectives (e.g., creation of fresh air corridors, maintaining the share of green spaces at over 50% until 2050, open spaces for different target groups, open spaces as part of social inclusion). Further, a separate chapter is dedicated to the topic "buildings", in which numerous targets are mentioned (e.g., use of buildings for greening and solar energy, satisfaction of heating requirements by renewable energies, reusing and recycling of materials from demolition, increase of refurbishment rates and use of insulation).

Zurich: The smart city strategy of Zurich itself does not contain any goals listed in the subject category. Nevertheless, there are some goals listed in the related general strategy document such as e.g., reduction of per capita energy consumption of currently 4.200 W to 2.000 W, refurbishment and insulation of the existing building stock and cutting CO_2 emissions to one ton per capita by 2050. Energy and climate related planning, green and blue infrastructure (public spaces) and building codes are mentioned in passing and in a non-binding manner.

Smart Mobility

London: Although London's smart city strategy lists several measures in connection with smart mobility, it does not refer to systematic indicators. One of London's central priorities is the "Smart Mobility Living Lab" in order to test, e.g., 5G connectivity or to foster innovations in relation to mobility. Transport for London (TfL, i.e., the government body in charge of the London's transport system) plays a crucial role in observing different kinds of movements (such as e.g., movement of trains), providing contactless payment methods in London's underground train system, running an open data portal for service and product developers and providing fast digital connectivity along the most relevant transport corridors in London's tube system.

Vienna: In Vienna's smart city concept, a separate chapter (p. 64 ff.) is dedicated to smart mobility. This is accompanied by extensive goals such as increasing the share of environmentally friendly modes of transport (including shared mobility) to 85% by 2030 and to well over 85% by 2050 (City of Vienna, 2019, p. 67), the reduction of private motorized vehicle ownership to 250 vehicles per 1.000 inhabitants by 2030 (City of Vienna, 2019, p. 69), maintaining short-distance journeys up to 5 km (out of which the majority shall be by bike or foot) (City of Vienna, 2019, p. 69), reduction of traffic crossing Vienna's borders with private motorized vehicles of 10% by 2030 (City of Vienna, 2019, p. 70) and CO_2-neutrality of the commercial traffic including freight transport within the municipal boarders by 2030 (City of Vienna, 2019, p. 70). These goals are combined with overall goals for the reduction of CO_2 emissions in the mobility sector in general (minus 50% by 2030 and minus 100% by 2050) as well as the reduction of the per capita energy consumption in the mobility sector of minus 40% by 2030 and minus 70% by 2050 (City of Vienna, 2019, p. 67). Local and regional accessibility is accounted for in the sense of maintaining Vienna as a city of short distances. International accessibility is not covered by the SCWFS. Sustainable transport policies are clearly mentioned by the above listed objectives. Nevertheless, there is no explicit account for an eco-friendly taxation policy. Vehicle sharing models (cars, bikes and self-driving e-taxis), on the other hand, are part of Vienna's smart city strategy. No targets are listed in the SCWFS for the technological infrastructure (smart information systems, smart cards, real-time information) in the mobility sector. These technological aspects are part of the digitalization chapter referring to e.g., smart grids and the collection of real-time data for urban development projects.

Zurich: As the smart city strategy of Zurich is held in a very abstract manner, smart mobility respectively future forms of mobility are generally laid out as one of the three focus areas stressing Zurich's goal of increasing the environmentally friendly mobility share and making use of new technological possibilities. Slightly more detail is given in Zurich's strategies for 2035 by setting the objective to satisfy additional demand for mobility by public transport, pedestrian and bicycle traffic. Street space for private motorized transport shall not be further increased. All other indicators such as freight transport, accessibility, transport policies such as taxation, sharing models and issues concerning the technological infrastructure are not mentioned in either document.

Smart Economy & Competitiveness

London: London's smart city strategy accounts for the indicators concerning knowledge-based economy, research institutions, innovativity and entrepreneurship including start-ups and employment growth in the digital sector. Numerous initiatives are listed, such as the establishment of the London Office of Technology & Innovation (LOTI) supporting capabilities and standards for innovation and digital collaboration of numerous authorities with London's City Hall, promoting medical-technological innovation and initiating civic innovation challenges. Economic perspectives with respect to the labor market are also mentioned within the digital sector (e.g., development of workforce digital capability, supporting computing skills and recognition of the responsibility of cultural organizations to integrate citizens in the digital domain as well as promoting gender diversity in tech-related professions). There is no information available on the other indicators, such as the local/regional GDP or the level and type of exported goods.

Vienna: Vienna's smart city objective is to significantly increase the share of the knowledge-based economy and technology-oriented services. Vienna plans to become one of Europe's most relevant innovation hubs by 2030 by attracting top international researchers and intends to foster international research cooperation. Further, challenges in relation to the smart city notion are to be resolved jointly between research institutions, universities, businesses and the local administration. The SCWFS in general accounts for supporting start-ups and especially within the framework of the circular economy by setting the objective to become a globally recognized center for a resource-efficient circular economy by 2030. Further, the local GDP is accounted for by setting the objective to constantly increase Vienna's productivity by supporting the city's wealth, resource efficiency and competitiveness. Regarding exported goods, there is no reference available. Nevertheless, Vienna intends to export its expertise on smart city services and products worldwide. With regard to Vienna's labor market, the smart city strategy of Vienna contains numerous goals summarized in a separate chapter on employment and on the economy. The main objectives towards the labor market are to secure and increase income and job satisfaction while simultaneously reducing social inequalities (e.g., equal job opportunities for women and men, inclusion of disabled people in the labor market) and provide fair working conditions and wages as well as social welfare schemes.

Zurich: The smart city strategy of Zurich does not offer relevant information for the given indicator set within this category with the exception of innovation to be fostered within Zurich's city administration. Further information – although still on a very general level – is given again by SZ 2035. Zurich recognizes its role as a financial center and has set itself the goal of strengthening its location through more innovation, and a knowledge society away from pure financial services. Further Zurich supports start-ups and innovative industry clusters in order to provide a diversified business location. Information on the city's competitiveness and ratio and type of exported goods is not available. Regarding Zurich's labor market, the city fosters its workforce especially with regards to technical experts as well as its labor laws to remain liberal. Nevertheless, there are no concrete smart city goals within Zurich's smart city notion available.

Smart People, Social and Human Capital

London: The SLT accounts for diversity in the tech sector – its goal is to promote diversity in order to address inequality when designing digital services. Further, London's smart city strategy includes goals referring to a more skilled workforce, again primarily within the tech-sector. Regarding poverty, the SLT includes the goal to prepare the relevant data in order to tackle fuel poverty. No evidence is given on, e.g., the distribution and growth of income, homelessness and social promotion. In contrast to this, London provides several concepts for connectedness and ICT inclusion of citizens (e.g., by an ICT program for over 50-year-olds and the unemployed, and programs for more digital literacy to counteract misinformation and digital fraud) as well as several concepts for building up social capital (e.g., digital campaigns to foster participation for diverse population groups and support of community-led participation).

Vienna: Social and ethnic plurality and diversity respectively demographic attributes are clearly recognizable, and are taken into account in several sections of the SCWFS. Within the thematic field of social inclusion Vienna is committed to promoting gender equality and equal opportunities for all citizens. Regarding low-threshold access to education in general as well as access to digital education in particular, the SCWFS provides a separate chapter on education with numerous objectives (e.g., educational institutions of high quality as early as possible until before compulsory schooling and the establishment of learning communities[19] tailored to local needs). Poverty is tackled in various ways by e.g., the goal of the general eradication of poverty, the objective of addressing energy poverty, tackling poverty with respect to social welfare schemes and opening up cultural offerings to citizens living below the poverty line. ICT inclusion is subject to the objective of providing comprehensive and needs-based programs for digital education. Civic participation and engagement are objectives in connection with making Vienna more resilient on a general level but also in connection with the realization of urban living labs and the application of digital tools supporting participation processes.

Zurich: Zurich's smart city strategy includes the goal of citizen participation at a very general level and is therefore more likely to fall under the following smart government indicators than under the concept of building social capital. All other indicators listed within this category according to Table 14 are not subject to the SSCZ. Nevertheless, SZ 2035 accounts for social solidarity and diversity by dedicating a full chapter to this topic. The goals are to maintain diversity and to align future municipal activities to the notion of social solidarity among generations and different demographics. Nevertheless, there is no explicit mentioning of an anti-poverty goal. The importance of education and research is mentioned in connection with Zurich's position as a financial center being home to a skilled workforce and the importance of social inclusion (equal opportunities and prospects for teenagers and young adults). Referring to ICT inclusion, Zurich is aware of the necessity to provide access to digital services to all groups of citizens. Nevertheless, there is no explicit objective available referring to ICT inclusion.

Smart Government

London: Digital participation and the creation of user-designed services belong to the first mission of London's smart city concept. This includes the establishment of civic platforms allowing citizen engagement, innovation and access to public services. London also provides for different strategies to strengthen open data, apps, privacy issues and e-government.

Vienna: The SCWFS accounts for all indicators in this category of smart governance. Vienna lists a separate chapter on digitalisation. Major goals are to make all municipal services (wherever possible) digitally and fully automated available by 2025, to use data, ICT and artificial intelligence tools to preserve resources and to keep the high quality of life as well as to allow transparency, ensure participation and to become a pioneer in open government.

[19] "Learning communities" according to the SCWFS are "networks to enhance interaction among nurseries, schools and non-school educational institutions such as libraries, youth centres and adult education centres in urban neighbourhoods" (City of Vienna, 2019, p. 119).

Zurich: Within its focus areas "digital city" and "smart participation", Zurich's smart city concept again lists – on a rather abstract level – the goals to further increase digitalization and to establish urban projects to experiment with innovative forms of participation. Strategies Zurich 2035 specify the importance of an easily accessible and reliable digital infrastructure as well as the provision of digitally available participation processes, transparent data and services - although without establishing a link to sustainability.

Smart Living and Quality of Living

London: In London's smart city strategy, there are several goals referring to health and improvement of and innovation within the health sector (e.g., data usage to inform the public on health campaigns, to increase participation levels in sports, secure use of personal medical data to improve healthcare as well as medical research). Regarding crime prevention SLT accounts for data usage to combat or prevent specific forms of crime (e.g., analyze data in order to tackle knife crime in specific urban areas, prevention of cyber-crime). The cultural aspects also refer to data usage and the role of cultural institutions to engage citizens in the digital sphere. Other smart city aspects within this category are not available.

Vienna: Although there is no separate chapter on smart living and quality of living, Vienna fully accounts for all indicators listed within this category. Vienna's central objectives within the healthcare section are to provide high-quality health care to every citizen and to achieve an extension of life expectancy of the Viennese citizens of two years by 2030. Regarding quality of life, Vienna has committed itself to preserve its high quality of life, inter alia by continuously investing in public urban infrastructure and fostering community cohesion. As maintaining quality of life is also one of the three headline goals of Vienna, this notion is present throughout the whole smart city concept. The provision of high-quality affordable housing has a long-lasting tradition in Vienna and is also a central pillar of the smart city concept (e.g., supply with municipal non-profit housing complexes, provision of public funding for housing projects meeting social criteria, supporting refurbishment and insulation activities, implementation of mixed-use areas containing residential use, workplaces and open space). Safety is listed in numerous contexts. Objectives therefore are improvement of traffic safety, maintaining a high level of subjective feeling of safety and the provision of digital safety in e-government services. Culture and low-threshold access to culture are part of Vienna's headline goal referring to quality of life. Therefore, the objective is to offer a diverse range of public engagement in order to provide a diverse arts and culture scene.

Zurich: Equal opportunities and maintaining and improving high quality of life refer to Zurich's main goals within the smart city strategy. In SZ 2035 this goal refers to one of the three main questions and is therefore a consistent target throughout the smart city concept. The provision of increasing the share of affordable housing is present, although Zurich also states that the city by itself is not able to overcome shortages on the housing market. Regarding safety and security, Zurich has set a goal to remain a safe and caring city by referring to the police and fire department. The role of culture is accounted for by setting the goal to offer a diverse, high-quality and contemporary cultural program.

Extent of ICTs

London: London has a very strong approach towards the use of ICT. The smart city concept is fully tech-driven. All planned measures are drafted on the basis of data collection, application and the use of smart technologies for both, enabling smart city goals as well as serving to improve efficiency.

Vienna: Vienna’s approach towards the use of ICT is clearly towards enabling and supporting its smart city (sustainability) objectives and less towards increasing efficiency. Examples for exceptions are the use of smart meters, the initiative towards a smart grid within the energy sector, and the goal to make municipal services digitally available wherever possible.

Zurich: ICT seems to play a rather subordinate role within the smart city concept of Zurich and is implemented to rather enable and support the smart city agenda.

4.3.3 Tools and timelines

Each smart city strategy described and evaluated above is associated with a timeframe for its implementation. Since these timelines are extremely variable in their precision, a general description of each timeframe is presented here.

London: The Smarter London Together smart city strategy provides no overall timeframe for the implementation of it five missions described in chapter 4.2.1. However, individual projects are linked to a time target. Therefore, within three years after publishing the smart city strategy, “report cards” refer to the completion of single projects being presented at the London Tech Week. For instance, the London Office for Data Analytics was to be launched within the first year; within year two and three new approaches to digital inclusion are to be developed.

Vienna: Vienna’s smart city strategy is laid out for the period of 2019 – 2050. The majority of objectives remain without a specific timeframe. However, each thematic field listed in the smart city strategy starts with a vision to be achieved by 2050. In addition, single objectives are linked with a target date – e.g., the production of renewable energies shall double between 2005 and 2030. Section 4.3.2 lists the target date for the most relevant objectives.

Zurich: Zurich's smart city strategy does not specify a timeframe for its implementation. The strategy is designed for the period 2019 - 2035. There are no further references for the individual goals. However, the strategies for Zurich (SZ 2035) refer to City Council decisions in some cases in their goals (e.g., increase the share of social housing from 25% to 33% by 2050). However, explicit timelines within SZ 2035 do not exist either.

4.3.4 Discussion of results and limitations to the study

The analysis of the smart city strategies of London, Vienna and Zurich – all wealthy European cities with comparable overall goals of urban development – showed that the concepts include vastly different approaches and starting points in terms of definitions and understandings of smart cities.

Based on the literature review, and the scholarly debate on the meaning of the smart city approach, this thesis has developed a smart city definition that both accounts for sustainability goals (e.g., smart environment, smart economy) while also stressing the importance of digitization and ICT as supporting technical frameworks and policies to support sustainability goals (e.g., the United Nation's Sustainable Development Goals, SDGs). The results of this discussion have even translated into norms and standards of the International Standards Organization (ISO) as well as European (and other) frameworks. This thesis has also developed a set of formal and content indicators based on the operational definition of a sustainable smart city in order to evaluate the smart city strategies of the selected cities.

In light of these definitions and debates, it is surprising that the smart city concepts of the three selected cities are as different as presented in sections 4.2 and 4.3. Vienna's smart city strategy is the only strategy that is a comprehensive and integrative one. It is comprehensive as it deals with most of the sustainability goals and indicators while also including the possibly substantial roles of ICT in sustainable urban development. It is also integrative as it includes the sustainability goals and all the relevant policy fields – e.g., transport, social security, environmental policies – in one document. Many policy objectives are also quantified in terms of time lines and concrete policy goals.

London's strategy is much more focused and detailed on the role of ICT, and clearly takes up a technology-driven smart city definition. However, even in this respect, the strategy is missing two important pieces of information. On the one hand, the link between the support and implementation of ICT, and the fulfilment of the other policy goals (e.g., mobility), is not made. For instance, smart transport systems should support a better use of public transport, but there is no reference made on how this link is established, or how and to what extent ICT can have an impact at all. On the other hand, there are merely no quantified objectives in the strategy.

Zurich's strategy is more sustainability-oriented than London's, but is a rather 'thin' strategy without concrete (quantified) objectives.

All three strategies, however, do not explain how possibly contradictory objectives should be solved; the three cities want to be more attractive in terms of locations for companies, but lack a discussion on how economic growth is dealt with in a world of scarce and often absolutely limited resources.

While the assessment of the three selected strategies clearly leads to the conclusion that the concepts are different, mainly because they are based on a different understanding of the smart city idea concept in the first place, the evaluation of the *smartness* of the city has to be separated from this analysis – and was also not the aim of this thesis. As it turns out, the contents, comprehensiveness and integrative approach of the smart city *concepts* do not seem to play a major role in the international rankings, such as the ones briefly presented in section 3.3. All three cities rank in the top group of comparable cities, certainly depending on the evaluation framework employed.

In this perspective, the results of this thesis also have to be interpreted cautiously, and there also certain limitations of the analysis. Firstly, the assessment of the smart city strategies in this thesis is, of course, driven by the prior definition of the sustainably smart city concept, and the formal and conceptual indicators derived from this definition.

Secondly, as it was also mentioned before, all three cities have passed numerous other policy concepts and urban development plans that certainly deal with many issues in separate documents. While Vienna has managed to include many other policy fields into the smart city strategy – which is an advantage for citizens as well as policy observers and scholars as it is comprehensive and easy to access –, the other two cities followed a different approach. London's strategy refers to the numerous other strategies without going into further urban development details, the links between ICTs and the other policy fields therefore remaining less clear. Zurich's strategy reads like as if policy-makers in Zurich wanted to show their citizens, and international observers, that they also had passed a smart city strategy. However, considering the contents of Zurich's strategy, it seems that the role and importance of the smart city policy papers are limited.

Thirdly, a different design of indicators drafted in this thesis in order to assess of the smart city concepts may have led to different results. Two caveats are of specific importance for the interpretation of the results in this regard. On the one hand, the choice of the indicators for the conceptual evaluation is crucial for the analysis. However, while this choice is certainly arbitrary to a certain extent, the development of indicators and the several dimensions and fields are derived from a thorough review of existing concepts and assessment frameworks. On the other hand, the operationalization of the indicators – a three-point scale, and verbal explanations and qualifications – can be criticized in terms of the validity and reliability for evaluation purposes (see also section 3.4 for more details on the researcher bias). As the assessment of the three smart city strategies selected has shown, the chosen evaluation framework has proven to be well suited for the discussion and qualification of the three concepts. It is the firm belief of the author that even a more detailed content analysis based on more quantitative and standardized context-related approaches would not have yielded different results of the assessment.

Fourthly, the analysis was deliberately limited to smart city strategies. Other policy papers were not included, on the one hand owing to the feasibility of a research work that would account for all relevant concepts, strategies and urban development plans of the three cities. Such approach would certainly be interesting, but would require an analysis of all strands of urban policies pursued in the three cities. On the other hand, the topic of this thesis is restricted to the conceptual analysis of smart city strategies, and the understanding of city policy-makers in regard to the definition and implementation of the smart city concept in their strategic papers. Therefore, the results of this thesis, of course, cannot assess the *smartness* of the city, but rather point to the disconnectedness between the smart city strategy taken at face value, and the position in various smart city rankings.

Having discussed the results and potential limitations of the analysis, we now turn to the last chapter of this thesis, the summary of the results, conclusions, and perspectives of future research in the field of smart cities.

5 SUMMARY AND CONCLUSION

5.1 Summary

This thesis started with a reference to the technology-driven first smart city concepts in a comprehensive literature review. The concept of a smart city was first proposed by technology companies (mainly companies in the information and communications technology [ICT] sector). However, the scholarly literature quickly discussed the smart city concept from various perspectives, focusing increasingly on the lack of the sustainability concept in urban development, as well as on the missed focus on governance and implementation issues. It became clear in the debate that increasing the use of smart technologies, and the general trends of digitalization, can improve the efficiency of resource use – a potentially necessary effect of smart technologies –, but that the concepts lacked references, for instance, to urban sustainable consumption and production, to the change of transport and energy systems, and social cohesion issues (such as the accessibility of technologies by social groups).

The smart city concept developed and proposed in this thesis therefore takes up both main strands of thought, and develops a definition of a smart sustainable city that is based on existing international frameworks of development, especially the United Nations' Sustainable Development Goals (SDGs). A smart city according to this understanding is a city that respects planetary boundaries, bases its development on the SDGs, and uses the latest technologies to support sustainable policy objectives. In this viewpoint, the concept of a sustainable urban development is therefore not limited to increasing the efficiency of the economy or of using resources, only concentrating on environmental concerns, but also accounting for social cohesion, equity and equality, participation and policy implementation (good governance).

Based on this broad understanding, a broad range of formal and content indicators was developed in order to assess and evaluate the smart city strategies of three selected cities, London, Zurich, and Vienna. The three cities, in turn, were chosen according to a number of considerations, such as comparability and similar national and international frameworks, and to a certain extent a proven smartness of urban policies.

The conceptual comparison and assessment of the three smart city strategies clearly pointed to the large variety of understandings of the smart city concept in the cities. London's strategy is mainly focused on digitalization, and therefore can be labeled as a clearly technology-driven strategy. Vienna's smart city strategy is the most comprehensive one, and is also the strategy that takes up the latest and most complete definition of a smart city by accounting for the SDGs. Zurich's strategy outlines policy objectives in the broad fields of urban smartness, but is a rather thin strategy mainly focusing on already existing urban development concepts and plans.

The differences between the smart city concepts are therefore not surprising in the sense that they can clearly be attributed to the specific understanding of the concept by the respective urban policy makers and city planners. As all three cities are ranked rather high in the various international smart city rankings, it seems that the importance of each of the smart city concepts for the concrete rank is limited. All concepts refer to numerous other policy documents and plans. With other words, if a smart city strategy does not account for some environmental indicator, that does not mean that there is no standard or guideline in other frameworks that would account for these indicators.

This thesis therefore has also shown that the broad scholarly debate on the definitions of smart city may be superfluous when the concrete impacts on urban policies are considered. Regardless of the drafting of a smart city strategy, the results of urban development policies can be more or less smart, depending on the implementation of other frameworks. However, a major conclusion of this thesis is that comprehensive, integrative and sustainable smart city concepts can nevertheless be very useful frameworks and guidelines for urban development, and can communicate smart sustainability goals and objectives to a wide range of local, regional and (inter-) national stakeholders.

5.2 Contribution to knowledge

This thesis has contributed to the existing knowledge on smart cities, concepts, strategies and evaluation frameworks, in the following respects briefly summarized:

- The thesis clarifies the smart city concept in the sense of combining the importance of Sustainable Development Goals (SDGs), and the implementation and use of ICT as supporting sustainability policies, and by stressing the necessity of linking and integrating these two large fields in order to facilitate a meaningful operational guidance for urban development policies.
- Furthermore, the empirical analysis has shed light on the different and often arbitrary definitions of smart cities used in the three cities that are often top-ranked in smart city assessments. It can reasonably be concluded that the concepts were decoupled from the scholarly debate. Vienna is most closely associated with the scientific state of the art - the smart city concepts of Zurich and London meet this requirement to a much lesser extent.
- Finally, the smart city concepts which may be perceived by citizens and scholars alike as guiding policy documents and strategies that include objectives, time lines, and instruments for implementation, often lack explicit operational contents to a surprisingly high degree.

5.3 Future research

There are a number of perspectives for future research on the smart city concepts and strategies. Firstly, this thesis has shown that there may be potentially conflicting policy goals included in the smart city strategies. While some of these contradictions originate in the Sustainable Development Goals (SDGs), which are not without internal conflicts as well, further research is still needed on the implementation of strict sustainability standards and policy objectives in urban development policies. From the viewpoint of the author, even the most refined and comprehensive smart city concepts such as the one issued by the City of Vienna lack important pieces of information on how to solve such conflicts. Urban and/or economic growth, liberalization and international competitiveness, the limitations of available natural resources, and the inclusiveness and social cohesion of societal development are all policy goals for which a joint achievement is highly doubtful.

Secondly, urban development is both dependent on local and regional policies, but is also substantially influenced by national and international policy frameworks. Resource and energy efficiency, for instance, might be influenced by smart metering or congestion charges, but eventually depends to a much higher extent on national and European carbon mitigation policies (e.g., carbon pricing, carbon border adjustment taxes). Cities certainly have only limited space for decision-making. In the opinion of the author, further research is needed to demonstrate which and to what extent urban policies can in reality affect, e.g., carbon mitigation, and which other more significant frameworks have to be changed in order to make urban policies more sustainable.

5.4 Conclusions in regard to the research question

The present thesis posed the question ***of how smart city concepts based on technology and/or governance and/or sustainability approaches can be evaluated by means of three selected European cities. The selected cities are London, Vienna and Zurich***.

This thesis has drafted and implemented a comprehensive evaluation and assessment framework for smart city concepts. The framework addresses the different fields and dimensions of smart city concepts on the basis of an extensive and critical literature review. Six relevant fields were identified (smart people, smart environment, smart governance, smart economy, smart living and smart mobility) that all have the origin in the United Nation's Sustainable Development Goals and consider ICTs as important but nonetheless, supporting role.

The implementation of the framework laid out in section 2.6 has shown that the three cities analyzed each have a very different approach to the concept of a smart city. London has a highly techno-centric smart city concept. Although other urban development strategies are mentioned, London's smart city approach does not have any explicit links with these strategies. The focus is on five main missions (user-designed services, city data, connectivity and smart streets, digital skills and digital collaboration). Within these goals, however, it becomes apparent that London does have very specific ideas. In the strategies mentioned by London (and the planned projects based on them), the city is very concrete and leaves behind general and non-binding formulations. In the assessment, this leads to London's measures - insofar as they appear in London's smart city strategy - also being predominantly rated with an indicator value of 3.

Vienna has by far the most comprehensive smart city concept. This strategy is explicitly based on the 17 SDGs and thus includes all individual smart city fields also listed in the literature. As a consequence, Vienna receives the maximum rating in almost all topic areas. Nevertheless, Vienna's smart city concept is clearly non-technology driven. The role of ICT and its possibilities is de facto not apparent. Although the Vienna smart city concept covers most of the topics of the three analyzed cities and can rightly be called complete, a weakness can also be seen in the fact that the conceptual and very superordinate strategy level is not left in order to become more concrete with regard to e.g., actual temporal implementation steps. This point of course is to be criticized in all three concepts. However, it is particularly noticeable in the case of Vienna due to the fact that it has the most concrete and comprehensive strategy.

Zurich's smart city strategy outlines policy objectives in the broad fields of urban smartness, but is a rather thin strategy mainly focusing on already existing urban development concepts and plans. Several fields of the smart city notion are recognizable, but nevertheless, remain on a very abstract level. The topics mentioned are less future-oriented, but often refer to existing strategies or already implemented measures. Therefore, Zurich shows predominately low assessment values. It clearly lacks specific conceptual approaches.

Followed by the above listed main research question, ***the following sub questions*** were answered:

- ***Which smart city concepts exist and how do technology driven concepts differ from socio-economic and governance concepts?***

The literature review has shown that the scope of smart city concepts is very broad. Numerous scholars have developed very different concepts and definitions of smart cities. There is no generally accepted smart city definition yet. Although the smart city idea has a technology-centric origin and is also strongly supported by IT companies, this thesis has shown that actual smartness is only achieved when the concept of sustainability, which includes socio-economic as well as governance issues, is applied. ICT plays an important role in this, but certainly only a supporting and enabling one, and can only be a means to an end.

- ***Which evaluation and indicator systems for smart city concepts are established?***

In the scientific literature, some concepts exist for the analysis of the smartness of a city, but not for the analysis of the respective concepts themselves. Therefore, the author of this paper created her own assessment concept. This is based on a verbal-hermeneutic analysis and a system of indicators to analyze and evaluate the formal and content dimensions of the concepts.

- ***What are the strengths and weaknesses of smart city concepts in three selected European cities?***

The clear strength of London's smart city strategy is its detailed focus on the use of ICT in urban development. However, the weakness of this focused and technology-driven concept is the lack of reference to sustainability and the SDGs as well as a clear embedding in an overarching urban development concept.

The strength of Vienna's smart city concept lies in the reference to the SDGs and a comprehensive understanding of urban sustainability. It is the strategy that most closely corresponds to a comprehensive sustainable smart city strategy, although the role of ICT is only dealt with very marginally, which could be interpreted as a certain weakness depending on one's perspective.

Zurich's smart city strategy is a short strategy referencing some urban issues but cannot be called complete by far. A strength is that it can be easily read and communicated, but a weakness is that hardly any concrete measures can be derived from it.

Therefore, a number of conclusions can be drawn from the results of this thesis. At the beginning of writing this thesis, the author implicitly started with the assumption that the smart city concept would be well-defined, and that the variations in the literature would be rather narrow. However, as the literature review as well as the empirical assessment of the smart city strategies of the three selected cities showed, there are various approaches to the smart city. From the viewpoint of the author, a meaningful and practical-policy oriented smart city concepts on the one hand needs to be based on the United Nations' Sustainable Development Goals (SDGs), and account for new technologies and digitalization as supporting and partially enabling infrastructure at the same time. Furthermore, cities miss the opportunities and the fruitfulness of the smart city approach if they consider it as a mere marketing tool, or if they only concentrate on technology-driven approaches.

In addition, urban stakeholders, especially citizens, businesses, and non-profit oriented institutions, should be informed about the city's future development perspectives. A comprehensive smart city strategy can detail such perspectives, and stakeholders would be able to base their decisions (e.g., the location of a business, investment decisions in terms of transport modes) in closer relation to urban development. Improved information can therefore increase the efficiency of various kinds of decisions.

Benefits of smart city concepts, finally, also lie in the realm of urban policy-making itself. Chaotic or uncoordinated urban policy making often leads to a waste of resources and, even more severe, to unsustainable urban development (e.g., urban sprawl, lack of public transportation, missed opportunities and reduced economies of scale and scope). Taking the smart city concept seriously by policy-makers improves urban policies, as the city administration and planning can refer to a comprehensive program and policy guidance.

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7 APPENDICES

7.1 Appendix 1: List of indicators according to Chapter 2.3

	Factor	Indicator
Smart Economy	Innovative spirit	R&D expenditure in % of GDP
		Employment rate in knowledge-intensive sectors
		Patent applications per inhabitant
	Entrepreneurship	Self-employment rate
		New businesses registered
	Economic image & trademarks	Importance as decision-making center (HQ etc.)
	Productivity	GDP per employed person
	Flexibility of labor market	Unemployment rate
		Proportion in part-time employment
	International embeddedness	Companies with HQ in the city quoted on national stock market
		Air transport of passengers
		Air transport of freight
Smart People	Level of qualification	Importance as knowledge center (top research centers, top universities etc.)
		Population qualified at levels 5-6 ISCED
		Foreign language skills
	Affinity to lifelong learning	Book loans per resident
		Participation in life-long learning in %
		Participation in language courses
	Social and ethnic plurality	Share of foreigners
		Share of nationals born abroad
	Flexibility	Perception of getting a new job
	Creativity	Share of people working in creative industries
	Cosmopolitanism/Open-mindedness	Voters turnout at European election
		Immigration-friendly environment (attitude towards immigration)
		Knowledge about the EU
	Participation in public life	Voters turnout at city elections
		Participation in voluntary work
Smart Governance	Participation in decision-making	City representatives per resident
		Political activity of inhabitants
		Importance of politics for inhabitants
		Share of female representatives
	Public and social services	Expenditures of the municipality per resident in PPS
		Share of children in day care
		Satisfaction of quality of schools
	Transparent governance	Satisfaction of transparency of bureaucracy
		Satisfaction with fight against corruption
Smart Mobility	Local accessibility	Public transport network per inhabitant
		Satisfaction with access to public transport
		Satisfaction with quality of public transport
	(Inter-)national accessibility	International accessibility
	Availability of ICT-infrastructure	Computers in households
		Broadband internet access in households
	Sustainable, innovative, safe transport systems	Green mobility share (non-motorized individual traffic)
		Traffic safety
		Use of economical cars
Smart Environment	Attractivity of natural conditions	Sunshine hours
		Green space share
	Pollution	Summer smog (Ozon)
		Particulate matter
		Fatal chronic lower respiratory diseases per inhabitant
	Environmental protection	Individual efforts on protecting nature
		Opinion on nature protection
	Sustainable resource management	Efficient use of water (use per GDP)
		Efficient use of electricity (use per GDP)

Smart Living	Cultural facilities	Cinema attendance per inhabitant
		Museums visit per inhabitant
		Theatre attendance per inhabitant
	Health conditions	Life expectancy
		Hospital beds per inhabitant
		Doctors per inhabitant
		Satisfaction with quality of health system
	Individual safety	Crime rate
		Death rate by assault
		Satisfaction with personal safety
	Housing quality	Share of housing fulfillment minimal standards
		Average living area per inhabitant
		Satisfaction with personal housing situation
	Education facilities	Students per inhabitant
		Satisfaction with access to educational system
		Satisfaction with quality of educational system
	Touristic attractivity	Importance as tourist location
		Overnights per year per resident
	Social cohesion	Perception of personal risk of property
		Poverty rate

Source: Giffinger et al. (2007), author’s draft.

7.2 Appendix 2: ISO 37120:2018 Sustainable cities and communities — Indicators for city services and quality of life as well as ISO 37122:2019 Sustainable cities and communities — Indicators for smart cities

Note: Cohen (2014) uses ISO 37120:2014 for his ranking. At this point, however, the more recent standard of 2018 is being depicted. In addition, the 2019 standard (ISO 37122:2019) lists established indicators specifically for smart cities.

	ISO 37120:2018 Sustainable cities and communities — Indicators for city services and quality of life	*ISO 37122:2019 Sustainable cities and communities — Indicators for smart cities*
Economy	○ City's unemployment rate (core indicator) ○ Assessed value of commercial and industrial properties as a percentage of total assessed value of all properties (supporting indicator) ○ Percentage of persons in full-time employment (supporting indicator) ○ Youth unemployment rate (supporting indicator) ○ Number of businesses per 100,000 population (supporting indicator) ○ Number of new patents per 100,000 population per year (supporting indicator) ○ Annual number of visitor stays (overnight) per 100,000 population (supporting indicator) ○ Commercial air connectivity (number of non-stop commercial air destinations) (supporting indicator) ○ Economy profile indicators	○ Percentage of service contracts providing city services which contain an open data policy ○ Survival rate of new businesses per 100,000 population ○ Percentage of the labour force employed in occupations in the information and communications technology (ICT) sector ○ Percentage of the labour force employed in occupations in the education and research and development sectors
Education	○ Percentage of female school-aged population enrolled in schools (core indicator) ○ Percentage of students completing primary education: survival rate (core indicator) ○ Percentage of students completing secondary education: survival rate (core indicator) ○ Primary education student–teacher ratio (core indicator) ○ Percentage of school-aged population enrolled in schools (supporting indicator) ○ Number of higher education degrees per 100,000 population (supporting indicator)	○ Percentage of city population with professional proficiency in more than one language ○ Number of computers, laptops, tablets or other digital learning devices available per 1,000 students ○ Number of science, technology, engineering and mathematics (STEM) higher education degrees per 100,000 population

Energy	○ Total end-use energy consumption per capita (GJ/year) (core indicator) ○ Percentage of total end-use energy derived from renewable sources (core indicator) ○ Percentage of city population with authorized electrical service (residential) (core indicator) ○ Number of gas distribution service connections per 100,000 population (residential) (core indicator) ○ Final energy consumption of public buildings per year (GJ/m2) (core indicator) ○ Electricity consumption of public street lighting per kilometre of lighted street (kWh/year) (supporting indicator) ○ Average annual hours of electrical service interruptions per household (supporting indicator) ○ Energy profile indicators	○ Percentage of electrical and thermal energy produced from wastewater treatment, solid waste and other liquid waste treatment and other waste heat resources, as a share of the city's total energy mix for a given year ○ Electrical and thermal energy (GJ) produced from wastewater treatment per capita per year ○ Electrical and thermal energy (GJ) produced from solid waste or other liquid waste treatment per capita per year ○ Percentage of the city's electricity that is produced using decentralised electricity production systems ○ Storage capacity of the city's energy grid per total city energy consumption ○ Percentage of street lighting managed by a light performance management system ○ Percentage of street lighting that has been refurbished and newly installed ○ Percentage of public buildings requiring renovation/refurbishment ○ Percentage of buildings in the city with smart energy meters ○ Number of electric vehicles charging stations per registered electric vehicle
Environment and climate change	○ Fine particulate matter (PM2.5) concentration (core indicator) ○ Particulate matter (PM10) concentration (core indicator) ○ Greenhouse gas emissions measured in tonnes per capita (core indicator) ○ Percentage of areas designated for natural protection (supporting indicator) ○ NO2 (nitrogen dioxide) concentration (supporting indicator) ○ SO2 (sulfur dioxide) concentration (supporting indicator) ○ O3 (ozone) concentration (supporting indicator) ○ Noise pollution (supporting indicator) ○ Percentage change in number of native species (supporting indicator)	○ Percentage of buildings built or refurbished within the last 5 years in conformity with green building principles ○ Number of real-time remote air quality monitoring stations per square kilometre (km2) ○ Percentage of public buildings equipped for monitoring indoor air quality
Finance	○ Debt service ratio (debt service expenditure as a percentage of a city's own-source revenue) (core indicator) ○ Capital spending as a percentage of total expenditures (core indicator) ○ Own-source revenue as a percentage of total revenues (supporting indicator) ○ Tax collected as a percentage of tax billed (supporting indicator) ○ Finance profile indicators	○ Annual amount of revenues collected from the sharing economy as a percentage of own-source revenue ○ Percentage of payments to the city that are paid electronically based on electronic invoices

Governance	○ Women as a percentage of total elected to city-level office (core indicator) ○ Number of convictions for corruption and/or bribery by city officials per 100,000 population (supporting indicator) ○ Number of registered voters as a percentage of the voting age population (supporting indicator) ○ Voter participation in last municipal election (as a percentage of registered voters) (supporting indicator)	○ Annual number of online visits to the municipal open data portal per 100,000 population ○ Percentage of city services accessible and that can be requested online ○ Average response time to inquiries made through the city's non-emergency inquiry system (days) ○ Average downtime of the city's IT infrastructure
Health	○ Average life expectancy (core indicator) ○ Number of in-patient hospital beds per 100,000 population (core indicator) ○ Number of physicians per 100,000 population (core indicator) ○ Under age five mortality per 1,000 live births (core indicator) ○ Number of nursing and midwifery personnel per 100,000 population (supporting indicator) ○ Suicide rate per 100,000 population (supporting indicator)	○ Percentage of the city's population with an online unified health file accessible to health care providers ○ Annual number of medical appointments conducted remotely per 100,000 population ○ Percentage of the city population with access to real-time public alert systems for air and water quality advisories
Housing	○ Percentage of city population living in inadequate housing (core indicator) ○ Percentage of population living in affordable housing (core indicator) ○ Number of homeless per 100,000 population (supporting indicator) ○ Percentage of households that exist without registered legal titles (supporting indicator) ○ Housing profile indicators	○ Percentage of households with smart energy meters ○ Percentage of households with smart water meters
Population and social conditions	○ Percentage of city population living below the international poverty line (core indicator) ○ Percentage of city population living below the national poverty line (supporting indicator) ○ Gini coefficient of inequality (supporting indicator) ○ Population and social conditions profile indicators	○ Percentage of public buildings that are accessible by persons with special needs ○ Percentage of municipal budget allocated for the provision of mobility aids, devices and assistive technologies to citizens with special needs ○ Percentage of marked pedestrian crossings equipped with accessible pedestrian signals ○ Percentage of municipal budget allocated for provision of programs designated for bridging the digital divide

Recreation	○ Square meters of public indoor recreation space per capita (supporting indicator) ○ Square meters of public outdoor recreation space per capita (supporting indicator)	○ Percentage of public recreation services that can be booked online
Safety	○ Number of firefighters per 100,000 population (core indicator) ○ Number of fire-related deaths per 100,000 population (core indicator) ○ Number of natural-hazard-related deaths per 100,000 population (core indicator) ○ Number of police officers per 100,000 population (core indicator) ○ Number of homicides per 100,000 population (core indicator) ○ Number of volunteer and part-time firefighters per 100,000 population (supporting indicator) ○ Response time for emergency response services from initial call (supporting indicator) ○ Crimes against property per 100,000 population (supporting indicator) ○ Number of deaths caused by industrial accidents per 100,000 population (supporting indicator) ○ Number of violent crimes against women per 100,000 population (supporting indicator)	○ Percentage of the city area covered by digital surveillance cameras

Solid waste	○ Percentage of city population with regular solid waste collection (residential) (core indicator) ○ Total collected municipal solid waste per capita (core indicator) ○ Percentage of the city's solid waste that is recycled (core indicator) ○ Percentage of the city's solid waste that is disposed of in a sanitary landfill (core indicator) ○ Percentage of the city's solid waste that is treated in energy-from-waste plants (core indicator) ○ Percentage of the city's solid waste that is biologically treated and used as compost or biogas (supporting indicator) ○ Percentage of the city's solid waste that is disposed of in an open dump (supporting indicator) ○ Percentage of the city's solid waste that is disposed of by other means (supporting indicator) ○ Hazardous waste generation per capita (tons) (supporting indicator) ○ Percentage of the city’s hazardous waste that is recycled (supporting indicator)	○ Percentage of waste drop-off centers (containers) equipped with telemetering ○ Percentage of the city population that has a door-to-door garbage collection with an individual monitoring of household waste quantities ○ Percentage of total amount of waste in the city that is used to generate energy ○ Percentage of total amount of plastic waste recycled in the city ○ Percentage of public garbage bins that are sensor-enabled public garbage bins ○ Percentage of the city’s electrical and electronic waste that is recycled
Sport and culture	○ Number of cultural institutions and sporting facilities per 100,000 population (core indicator) ○ Percentage of municipal budget allocated to cultural and sporting facilities (supporting indicator) ○ Annual number of cultural events per 100,000 population (e.g. exhibitions, festivals, concerts) (supporting indicator)	○ Number of online bookings for cultural facilities per 100,000 population ○ Percentage of the city’s cultural records that have been digitized ○ Number of public library book and e-book titles per 100,000 population ○ Percentage of city population that are active public library users
Telecommunication	○ Number of internet connections per 100,000 population (supporting indicator) ○ Number of mobile phone connections per 100,000 population (supporting indicator)	○ Percentage of the city population with access to sufficiently fast broadband ○ Percentage of city area under a white zone/dead spot/not covered by telecommunication connectivity ○ Percentage of the city area covered by municipally provided Internet connectivity

Transportation	○ Kilometers of public transport system per 100,000 population (core indicator) ○ Annual number of public transport trips per capita (core indicator) ○ Percentage of commuters using a travel mode to work other than a personal vehicle (supporting indicator) ○ Kilometers of bicycle paths and lanes per 100,000 population (supporting indicator) ○ Transportation deaths per 100,000 population (supporting indicator) ○ Percentage of population living within 0,5 km of public transit running at least every 20 min during peak periods (supporting indicator) ○ Average commute time (supporting indicator) ○ Transportation profile indicators	○ Percentage of city streets and thoroughfares covered by real-time online traffic alerts and information ○ Number of users of sharing economy transportation per 100,000 population ○ Percentage of vehicles registered in the city that are low-emission vehicles ○ Number of bicycles available through municipally provided bicycle-sharing services per 100,000 population ○ Percentage of public transport lines equipped with a publicly accessible real-time system ○ Percentage of the city's public transport services covered by a unified payment system ○ Percentage of public parking spaces equipped with e-payment systems ○ Percentage of public parking spaces equipped with real-time availability systems ○ Percentage of traffic lights that are intelligent/smart ○ City area mapped by real-time interactive street maps as a percentage of the city's total land area ○ Percentage of vehicles registered in the city that are autonomous vehicles ○ Percentage of public transport routes with municipally provided and/or managed Internet connectivity for commuters ○ Percentage of roads conforming with autonomous driving systems ○ Percentage of the city's bus fleet that is motor-driven
Urban/local agriculture and food security	○ Total urban agricultural area per 100,000 population (core indicator) ○ Amount of food produced locally as a percentage of total food supplied to the city (supporting indicator) ○ Percentage of city population undernourished (supporting indicator) ○ Percentage of city population that is overweight or obese — Body Mass Index (BMI) (supporting indicator)	○ Annual percentage of municipal budget spent on urban agriculture initiatives ○ Annual total collected municipal food waste sent to a processing facility for composting per capita (in tons) ○ Percentage of the city's land area covered by an online food-supplier mapping system

Urban planning	○ Green area (hectares) per 100,000 population (core indicator) ○ Areal size of informal settlements as a percentage of city area (supporting indicator) ○ Jobs–housing ratio (supporting indicator) ○ Basic service proximity (supporting indicator) ○ Urban planning profile indicators	○ Annual number of citizens engaged in the planning process per 100,000 population ○ Percentage of building permits submitted through an electronic submission system ○ Average time for building permit approval (days) ○ Percentage of the city population living in medium-to-high population densities
Wastewater	○ Percentage of city population served by wastewater collection (core indicator) ○ Percentage of city's wastewater receiving centralized treatment (core indicator) ○ Percentage of population with access to improved sanitation (core indicator) ○ Compliance rate of wastewater treatment (supporting indicator)	○ Percentage of treated wastewater being reused ○ Percentage of biosolids that are reused (dry matter mass) ○ Energy derived from wastewater as a percentage of total energy consumption of the city ○ Percentage of total amount of wastewater in the city that is used to generate energy ○ Percentage of the wastewater pipeline network monitored by a real-time data-tracking sensor system
Water	○ Percentage of city population with potable water supply service (core indicator) ○ Percentage of city population with sustainable access to an improved water source (core indicator) ○ Total domestic water consumption per capita (liters/day) (core indicator) ○ Compliance rate of drinking water quality (core indicator) ○ Total water consumption per capita (liters/day) (supporting indicator) ○ Average annual hours of water service interruptions per household (supporting indicator) ○ Percentage of water loss (unaccounted for water) (supporting indicator)	○ Percentage of drinking water tracked by real-time, water quality monitoring station ○ Number of real-time environmental water quality monitoring stations per 100,000 population ○ Percentage of the city's water distribution network monitored by a smart water system ○ Percentage of buildings in the city with smart water meters

Sources: ISO (2018) and ISO (2019), author's draft.