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Faculty of Economics and Administration
Department of System Engineering and Informatics

Analysis and comparison of indicators for evaluation of Smart Cities development

Bachelor's Thesis

2024 Adwoa Boahemaah

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Theses guidelines

The aim of the thesis is to analyse indicators used to evaluate development of Smart Cities and compare selected cities in terms of most relevant indicators.
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– Reference to the theoretical background of the subject matter
– Definition and development of the term Smart City
– Identification and description of relevant characteristics and indicators
– Data analysis and comparison of selected cities
– Results and discussion

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SHARIFI, Ayyoob. A critical review of selected smart city assessment tools and indicator sets. *Journal of Cleaner Production*, 2019, 233: 1269-1283.
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Declaration:

I declare:

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ANNOTATION

The thesis analyses indicators used to evaluate development of Smart Cities and compares selected cities in terms of most relevant indicators. It contains a procedure for solving this issue, which consists of the analysis of the secondary data. Selected Smart Cities are compared, the results are discussed, and the recommendations are provided.

KEYWORDS

Smart Cities, indexes, indicators, analysis, comparison

NÁZEV

Analýza a porovnání indikátorů pro hodnocení rozvoje Smart Cities

ANOTACE

Tato práce analyzuje indikátory používané pro hodnocení rozvoje Smart Cities a porovnává vybraná města z hlediska nejvýznamnějších indikátorů. Obsahuje postup řešení této problematiky, který spočívá v analýze sekundárních dat. Vybraná Smart Cities jsou porovnána, výsledky diskutovány a poskytnuta doporučení.

KLÍČOVÁ SLOVA

Smart Cities, indexy, indikátory, analýza, porovnání

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List of abbreviations

AI	Artificial Intelligence
CIMI	Cities in Motion Index
GCI	Global Cities Index
GCO	Global Cities Outlook
ICT	Information and Communications Technologies
IoT	Internet of Things
KPIs	Key Performance Indicators
ML	Machine Learning
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
SCG	Smart City Governments
SCI	Smart City Index
SCTD	Smart City Technology division
SMG	Seoul Metropolitan Government
UPSUF	Urban Planning Sustainability Framework

INTRODUCTION

The 21st century has seen a rapid acceleration in urbanization, with over half of the global population residing in cities. This shift towards urban living has created complex challenges that require innovative solutions (Scott, 2012). Smart Cities have emerged as a promising solution, harnessing advanced technologies and data analysis to enhance the quality of life for citizens, improve sustainability, and streamline urban services. Smart Cities use data-driven strategies and advanced technologies to address urban issues efficiently. They aim to optimize transportation, enhance energy efficiency, and foster data-informed governance, all with the overarching goal of improving the urban experience (Kumar et al., 2020).

The development of Smart Cities is a multifaceted endeavour that demands the use of various indicators to measure progress and assess success (Caird and Hallett, 2019; Sharifi, 2019). Measuring the performance of Smart Cities is essential to ensure their effectiveness. With the use of various indicators, it is possible to capture the impact of digital innovation in cities on outcomes for citizens (OECD, 2020). The selection of the right indicators is a challenge because every city is different. They have their own characteristics, challenges, and goals. The indicators need to reflect the uniqueness of each city while still being comparable to others. This balance is critical for evaluating Smart Cities effectively (Huovila et al., 2019; OECD, 2020; Pira, 2021).

The existing literature on Smart City indicators is diverse, revealing that there is no consensus on the best set of indicators for evaluating Smart City development. Various studies have proposed different sets of indicators, each with its strengths and weaknesses, emphasizing different aspects of Smart Cities, such as economy, environment, living, people, transportation, and government (Huovila et al., 2019; Musterd and Murie, 2011; Pérez et al., 2020; Pira, 2021; Sharifi, 2019). That is why choosing the best indicators that are universally applicable is challenging because Smart Cities are context dependent. A Smart City in one region may prioritize certain aspects over others based on its unique challenges and opportunities. For instance, a city with a growing population might prioritize indicators related to transportation and living conditions, while a city with a strong industrial base might focus more on economic and environmental indicators (Huovila et al., 2019; Song et al., 2017).

Therefore, this thesis aims to analyse and compare the different sets of indicators proposed in the literature, with the goal of identifying their strengths and weaknesses. This will not only

provide a comprehensive understanding of the current state of Smart City evaluation but also contribute to the ongoing discourse on developing a more standardized and universally applicable set of indicators for Smart City development.

Thus, it is important to examine the indicators used for evaluating Smart Cities development, identify and compare existing benchmarking frameworks, their strengths and weaknesses as well as their structure and progress in time. By identifying the most effective indicators, cities can focus their efforts on the areas that will have the most significant impact on their citizens' quality of life. This will help policymakers and city planners to select the most appropriate indicators for their specific city, considering their unique characteristics, challenges, and goals.

The aim of this thesis is to analyse indicators used to evaluate development of Smart Cities and compare selected cities in terms of most relevant indicators. To achieve this overarching goal, the thesis is guided by several specific objectives:

- To identify and review existing Smart City evaluation tools, models, and frameworks.
- To select and classify relevant Smart City indicators across various indexes and rating systems.
- To perform a comparative analysis of selected Smart Cities based on the indicators.
- To derive results and recommendations for Smart City development and evaluation.

To address these objectives, this thesis first presents a theoretical background on the topic. The next chapter is focused on identification and description of Smart Cities characteristics and indicators, including tools and frameworks for evaluation of Smart Cities and structure and indicators of Smart Cities. Data analysis and comparison of selected Smart Cities are included in the next chapter. It also provides the research methodology and design. Results are discussed in the forthcoming chapter.

1 THEORETICAL BACKGROUND

1.1 THE ROLE OF ICT IN URBAN DEVELOPMENT AND PLANNING

Information and Communication Technology (ICT), represents a broad category encompassing various technologies and systems used to collect, transmit, store, and manage information. ICT is a convergence of telecommunication technologies, such as the internet and mobile networks, with computer-based technologies for data processing and information dissemination. It includes a spectrum of tools, from personal computers and smartphones to large-scale data centres and communication networks (Mishra and Mishra, 2014). ICT is an essential part of modern society, influencing multiple facets of our lives, including education, healthcare, entertainment, governance, and urban development (Allam and Newman, 2018). It addresses urban challenges like traffic congestion, energy efficiency, and e-governance. The high population density in cities amplifies the importance of ICT for efficient resource management, intelligent transportation systems, and data-driven decision-making (Neirotti et al., 2014; Santinha and Anselmo de Castro, 2010).

ICT plays an instrumental role in shaping the landscape of urban development and planning. This transformative influence stems from the integration of digital technologies and data-driven approaches into the traditional urban development processes. Here are key aspects of its role:

- Enhances urban infrastructure: ICT enables the development of smart infrastructure, such as intelligent transportation systems, energy-efficient buildings, and smart grids, which optimize traffic flow, reduce congestion, and promote sustainability (Telang et al., 2021).
- Improves service delivery: ICT-driven Smart Cities provide innovative and efficient services to their residents, including e-governance initiatives, online payment systems, e-healthcare, and digital education platforms. These services lead to improved public service delivery, transparency, and responsiveness (Kumar et al., 2020).
- Promotes data-driven decision-making: The digital layer of Smart Cities generates a continuous stream of data from various sources, which can be analysed to identify patterns, anticipate needs, and optimize resource allocation. This data-driven approach is vital for predictive analytics, helping cities prepare for future challenges such as climate change, population growth, and disaster resilience (Shahat Osman and Elragal, 2021).

- Fosters citizen engagement and empowerment: ICT bridges the gap between city administrations and their constituents, allowing citizens to actively participate in urban governance and decision-making. Citizens can provide feedback, report issues, and collaborate with city authorities to improve their communities, fostering a more transparent and responsive relationship (Garcia Alonso and Lippez-De Castro, 2016).

Electronic government (e-government) is the use of ICT to enhance the delivery of government services to citizens. E-government has significant implications for Smart Cities development, as it can help to improve the efficiency and transparency of government operations. E-government technologies include tools such as online portals for accessing government services, digital identity systems, or open data platforms. Smart Cities might use these e-government technologies to provide citizens with real-time information about bus schedules, enable patients to schedule appointments with healthcare providers online, or download open datasets about budgets or tenders (Allam and Newman, 2018; Mechant and Walravens, 2018).

1.2 DEFINITION AND DEVELOPMENT OF THE TERM SMART CITY

1.2.1 Definition of the term Smart City

Cities and villages are two distinct types of human settlements. Cities are typically larger and more densely populated than villages. According to the United Nations, a city is defined as a settlement with a population of 10,000 or more, while a village is defined as a settlement with a population of less than 10,000. Cities and villages have different infrastructures, services, and economic activities (Bibby and Shepherd, 2004; United Nations, 2001). This quantitative distinction is a starting point, but it only hints at the profound differences between these two settlement types. Cities often serve as hubs of commerce, industry, culture, and governance. They house diverse economic activities, educational institutions, healthcare facilities, and cultural amenities. The concentration of resources and opportunities in urban environments fosters economic development and innovation (Halegoua, 2020; Musterd and Murie, 2011).

Smart Cities are an emerging concept that has gained significant attention in recent years. The concept of Smart Cities refers to the use of technology and data to improve the quality of life for citizens, enhance sustainability, and promote economic development. Many other terms have been used to describe the Smart City idea, including the terms knowledge city, intelligent city, digital city, information city, as well as the ubiquitous city. A Smart City, on the other

side, represents a more advanced level of intelligent and digital cities (Halegoua, 2020; Santinha and Anselmo de Castro, 2010; Song et al., 2017).

Caragliu et al. (2009) call a city smart when investments in human and social capital, as well as traditional transportation and modern ICT-based infrastructure, fuel sustainable economic growth and a high quality of life, with wise management of natural resources through participatory government. Peirce et al. (2013) define Smart Cities as places where information technology is deliberately used to improve city operations and management, enable innovation in public services and governance, and increasingly to improve long-range planning. Kitchin (2014) defines a Smart City as a place where ubiquitous computing is increasingly used to monitor and manage various aspects of urban life, with its economy and governance driven by innovation and creativity. Lee et al. (2014) suggest that an effective and sustainable Smart City emerges because of dynamic processes in which public and private sector actors coordinate their activities and resources on an open innovation platform, with the goal of creating sustainable value for citizens, employees, and shareholders.

Sikora-Fernandez and Stawasz (2016) argues that a Smart City becomes real when people can deal with open technologies to improve their surroundings. De Lange and De Waal (2017) argue that the concept of a Smart City is mainly used to describe technologies that make cities more efficient and enjoyable. Kumar et al. (2018) define a Smart City as a place that efficiently and effectively manages urban life by focusing on environmental, economic, and social aspects. According to Yusuf et al. (2019), a Smart City aims to resolve urban problems and revitalise the city's environmental and social imbalances through the efficient redirection of information and ICT-based technology connected as urban infrastructure.

Barcelona City Hall defines a Smart City as a high-tech-intensive and advanced city that connects people, information, and city elements using new technologies to create a sustainable greener city, a competitive and innovative commerce, and an increased life quality (Bakıcı et al., 2013). Similarly, Amsterdam City Hall posits that a Smart City specifically uses innovative technology and is willing to change behaviour related to energy consumption to tackle climate goals (Riva Sanseverino et al., 2017). Although there are several definitions of Smart Cities, most of them encompass the broad use of technology to gather and process information for monitoring, optimising, and managing a city.

1.2.2 Development of the term Smart City

The concept of Smart Cities, with its emphasis on technology-driven urban development, has undergone a remarkable evolution over the past few decades. This innovative urban model has deep roots in visionary ideas, socio-technological shifts, and the pressing need to address the complex challenges posed by rapid urbanization and sustainability concerns (Kumar et al., 2020).

Visionaries such as Le Corbusier and Ebenezer Howard proposed innovative urban planning concepts that hinted at a future where technology would play a central role in creating more efficient, interconnected, and liveable cities. These early concepts laid the groundwork for later Smart City thinking (Sewell, 1993). The late 20th century brought about the digital revolution, marked by the widespread adoption of computers, the internet, and mobile communication. This era served as a catalyst for the integration of digital technologies into urban contexts. Cities across the globe were grappling with the challenges of rapid urbanization, including population growth, increased resource consumption, and escalating environmental concerns. It became evident that technology could offer solutions to these complex urban issues (Allam, 2019; Song et al., 2017).

In the late 20th and early 21st centuries, cities began to embrace digital technologies for administrative purposes. E-governance initiatives, digital record-keeping, and online citizen services became integral to urban administration. These digital advancements not only improved the efficiency and transparency of city governance but also laid the groundwork for more comprehensive Smart City strategies (Allam, 2019; Halegoua, 2020). Growing concerns about environmental sustainability, resource depletion, and the ecological impact of urbanization played a pivotal role in shaping the Smart City concept (Puchol-Salort et al., 2021). Cities started exploring innovative solutions to reduce energy consumption, combat pollution, and manage resources more efficiently. Sustainability became a defining principle, and environmental stewardship was integrated into Smart City agendas (Allam, 2019).

A watershed moment in the development of Smart Cities was the emergence of the Internet of Things (IoT). This technological revolution allowed devices to connect and communicate with each other, leading to the creation of interconnected ecosystems within cities. Sensors played a central role in collecting real-time data for urban monitoring and management. IoT technology provided the foundational infrastructure for Smart City initiatives (Jin et al., 2014). As the Smart City concept gained momentum, the development of evaluation models, frameworks,

and indicator systems became paramount. These tools provided a structured approach to assess and compare Smart City development, contributing to the standardization of practices in the field (Borsekova et al., 2018, Lai and Cole, 2023; Sharifi, 2019; Zaidan et al., 2022).

1.2.3 Technologies and trends of Smart Cities

Technologies and trends of Smart Cities can be discussed in relation to different application areas of Smart Cities such as (Kang and Wang, 2020; Lombardi et al., 2012):

- Smart Governance – the use of technology to improve the efficiency and transparency of government operations such as online portals for accessing government services, digital identity systems, and open data platforms.
- Smart Economy – the use of technology to promote economic growth and development such as smart transportation systems, energy management systems, and e-commerce platforms.
- Smart Living – improvement of the quality of life for city residents that includes smart home systems, telemedicine, and smart waste management systems.
- Smart Mobility – optimization of transportation systems within the city using smart traffic management systems, electric vehicle charging stations, and smart public transportation systems.
- Smart Environment – the use of technology to monitor and manage the city's natural resources such as water and energy.

Technology plays a crucial role in the development and operation of Smart Cities. It enables the collection and analysis of data from various sources, allowing city officials to make informed decisions and optimize urban systems. Some of the key technologies and trends used in Smart Cities include:

- IoT – IoT devices collect and transmit data from various sources, such as sensors and cameras, to monitor and manage urban systems in real-time. This technology helps to improve the efficiency and sustainability of urban infrastructure, such as transportation, energy, and waste management systems (Paul and Jeyaraj, 2019).
- Big Data and Analytics – by collecting and analysing large amounts of data, city officials can identify trends and patterns to inform decision-making and improve city operations. This technology helps to optimize resource allocation and identify areas for improvement (Ali et al., 2016).

- Artificial Intelligence (AI) and Machine Learning (ML): AI and ML algorithms can be used to analyse data and predict future trends, helping city officials to proactively address urban challenges such as traffic management, energy consumption, and urban planning (Yigitcanlar and Cugurullo, 2020).
- Increased investment in smart infrastructure such as IoT, 5G networks, and advanced analytics, to support the development of Smart City applications. This infrastructure enables the collection and analysis of data from various sources, allowing city officials to make informed decisions and optimize urban systems (Kalenyuk et al., 2023).
- Increased focus on sustainability with investments in smart energy management systems, electric vehicle infrastructure, and green spaces. This focus on sustainability helps to reduce the environmental impact of urban development and improve the overall quality of life for city dwellers (Calvillo et al., 2016).
- Collaboration between public and private sectors to achieve sustainable urban development, these partnerships help to facilitate the adoption and implementation of smart technologies in cities (Lam and Yang, 2020).

2 IDENTIFICATION AND DESCRIPTION OF CHARACTERISTICS AND INDICATORS

2.1 TOOLS AND FRAMEWORKS FOR EVALUATION OF SMART CITIES

Evaluation frameworks are essential in urban planning as they provide a structured approach to assessing the performance of cities and identifying areas for improvement. There are three main categories of tools and frameworks for evaluation of Smart Cities: 1) frameworks developed by international organizations and groups such as United Nations, World Bank, or Organisation for Economic Co-operation and Development (OECD), 2) frameworks developed by respective countries or cities – these are usually country-related with unique specifics and cannot be meaningfully compared on a global scale, and 3) frameworks developed by researchers or research organizations – these are usually produced as parts of research projects. There exist significant disparities among the various frameworks created up to this point. These disparities primarily arise from the rapid pace of technological progress and the diverse structural characteristics of cities.

The Urban Sustainability Framework (USF) developed by the Global Platform for Sustainable Cities is an integrated approach to help cities understand their urban sustainability status, define their vision, and formulate and implement an action plan. The Urban Planning Sustainability Framework (UPSUF) developed by Puchol-Salort et al. (2021) is a comprehensive framework that combines sustainability evaluation, design solutions, and planning systems to address multifunctional design solutions in urban planning. The UPSUF aims to:

1. Assess the sustainability of urban planning interventions: The UPSUF evaluates the environmental, economic, and social impacts of urban planning interventions. This includes measuring the reduction of greenhouse gas emissions, the promotion of resource efficiency, and the enhancement of social equity and resilience.
2. Identify and evaluate design solutions that promote sustainable urban development: The UPSUF identifies and evaluates design solutions that contribute to sustainable urban development. These solutions may include green infrastructure, smart growth strategies, and innovative transportation systems.
3. Integrate sustainability evaluation into the planning process to ensure that sustainable principles are considered throughout the planning process: The UPSUF emphasizes the importance of incorporating sustainability principles into the planning process from the

beginning. This includes setting clear sustainability goals, evaluating the sustainability implications of planning decisions, and adapting the planning process to address emerging sustainability challenges.

Evaluation Framework for the Use of Scenarios in Urban Planning framework is derived from a review of scenario planning evaluation studies in the urban planning, environment, and management fields (Goodspeed, 2017). It aims to:

1. Evaluate the effectiveness of urban scenario planning methods in addressing urban land use, transportation, economic development, and resilience issues: The framework assesses the ability of scenario planning methods to address various urban issues, such as land use, transportation, economic development, and resilience.
2. Identify and assess psychological, institutional, and system outcomes at the individual, organizational, and geographic unit levels: The framework examines the impacts of scenario planning on individuals, organizations, and geographic units. This includes measuring changes in individual attitudes, organizational practices, and geographic unit outcomes.
3. Extend the performance approach to plan evaluation by including, but extending beyond, whether the plan was useful for public-sector decision-making: The framework goes beyond traditional performance evaluation by assessing the quality of the planning process and the degree to which it engaged stakeholders and promoted collaboration. This includes evaluating the transparency, inclusiveness, and effectiveness of stakeholder engagement processes and the extent to which the planning process fostered collaboration among various stakeholders.

Evaluation is a crucial aspect of urban planning, as it helps stakeholders understand the effectiveness of their planning strategies and identify areas for improvement. By conducting evaluations, urban planners can gather valuable insights into the successes and challenges of their projects, enabling them to make informed decisions and adapt their strategies as needed. The key importance of evaluation in urban planning include (Goodspeed, 2017):

1. Identifying Successes and Challenges: Evaluation allows urban planners to identify the strengths and weaknesses of their projects, helping them to understand which strategies are working and where improvements can be made.

2. Informing Decision-Making: Evaluation provides valuable information to decision-makers, enabling them to make informed choices about the direction of urban planning projects and policies.
3. Promoting Transparency and Accountability: By conducting evaluations, urban planners demonstrate their commitment to transparency and accountability, ensuring that their actions are open to scrutiny and that they are working in the best interests of their constituents.
4. Guiding Future Planning Efforts: Evaluation results can be used to refine and improve urban planning strategies, ensuring that future projects are more effective and better tailored to the needs of the community.
5. Supporting Resource Allocation: Evaluation can help identify areas where additional resources are needed or where existing resources can be redeployed more effectively, ensuring that urban planning projects are conducted in a cost-effective and efficient manner.

Common evaluation criteria in urban planning include a variety of factors that help planners assess the effectiveness and sustainability of their projects. They include (Caird and Hallett, 2019; Chakhar et al., 2005; Goodspeed, 2017; Zhang et al., 2013):

- Land Use and Urban Design: This criterion focuses on the layout and organization of urban spaces, ensuring that they are functional, efficient, and aesthetically pleasing.
- Environmental Impact: This criterion assesses the environmental impact of urban development, including energy efficiency, waste reduction, and the use of renewable energy sources.
- Social Equity: This criterion evaluates the social impact of urban development, ensuring that all residents have access to quality housing, education, healthcare, and other essential services.
- Economic Viability: This criterion considers the economic viability of urban development by promoting sustainable economic growth, fostering job creation, and encouraging private investment in sustainable infrastructure.
- Access to Amenities and Services: This criterion ensures that all residents have access to essential services, such as healthcare, education, and public transportation.

- Social Cohesion and Community Engagement: This criterion focuses on promoting social cohesion and community engagement, ensuring that residents feel connected to their neighbourhoods and have opportunities to participate in civic life.
- Resource Efficiency: This criterion evaluates the efficient use of resources in urban development, such as energy-efficient buildings, green infrastructure, and sustainable water management.
- Resilience to Climate Change and Environmental Challenges: This criterion assesses the resilience of urban development to climate change and other environmental challenges, such as floods, droughts, and extreme weather events.
- Smart City Technologies: This criterion evaluates the integration of Smart City technologies into urban planning projects, ensuring that they promote sustainable urban development and improve the quality of life for urban residents.

2.2 STRUCTURE AND INDICATORS OF SMART CITIES

The following Table 1 provides an overview of indexes and rankings that belong to the first category of tools and frameworks (see the previous section). It should be noted that each output presented as an index or ranking is based on the benchmarking framework. The list of resources included in the table was developed by searching for respective keywords (Smart City AND index OR ranking OR framework OR report) using Google and Bing search engines.

The Cities in Motion Index (CIMI) is published by the IESE Business School from 2014. The Smart City Governments (SCG) report evaluates the development of 50 Smart Cities from a city government's perspective. The last edition is from 2021. The IMD Smart City Index (SCI) was firstly published in 2019 and balances the assessment of economic and technological aspects of Smart Cities with a consideration of the humane dimensions such as quality of life etc. The Global Cities Index (GCI) and Global Cities Outlook (GCO) are published by Kearney in the Global Cities Report since 2008. The Global Power City Index (GPCI) is published by the Mori Memorial Foundation since 2015. Each of these indexes consists of different dimensions, such as quality of life or smart education, and several indicators that measure concrete actions or improvements under respective dimensions, such as numbers of artificial intelligence projects or electric vehicle charging stations. Some of these indexes also consist of sub-indexes, represented by dimensions / categories / areas, that can be used to evaluate Smart Cities.

There are also other indexes, such as the Cities of the Future Index by EasyPark or the SmartEcoCity Index by SmartEcoCity, but they were not included in the table because they are only one-time reports.

Table 1: Overview of Smart Cities indexes and rankings. Source: own processing.

Smart City index / ranking	**Publisher**	**Number of editions**	**Latest edition**	
			Published	**Number of cities covered**
CIMI	IESE Business School	8	2022	183
GCI	Kearney	13	2023	156
GPCI	Mori Memorial Foundation	9	2023	48
SCG	Eden Strategy Institute	2	2021	50
SCI	IMD Business School	4	2023	141

Table 2 then presents a list of research papers and studies that are focused on evaluations and benchmarking of Smart Cities. The list of resources included in the table was developed by searching for respective keywords (Smart City AND index OR ranking OR framework OR report) using Scopus, an Elsevier's abstract and citation database, and Google Scholar, which provides access to broadly search for scholarly literature. In contrast to tools and frameworks used to evaluate Smart Cities presented in Table 1, research papers and studies introduce different tools, frameworks, indexes, rankings, dimensions, and indicators that are published only once. The structure of these outputs also differs.

Giffinger and Gudrun (2010) question the efficacy of Smart City rankings as tools for urban enhancement and investment attraction. Albino et al. (2015) dissect the essence of Smart Cities, their defining features, and performance metrics. Purnomo and Prabowo (2016) offer a systematic review of Smart City evaluation indicators, while Hara et al. (2016) propose new Key Performance Indicators (KPIs) tailored for sustainable Smart Cities. Battarra et al. (2018) investigate the actionable outcomes linked to these indicators, and Picioroagă et al. (2018) focus on defining and assessing KPIs for Smart City progress. Petrova-Antonova and Ilieva (2018) survey the prevalent performance and sustainability indicators, Dall'O' (2020) examines

sustainable Smart City metrics, and Alderete (2020) looks at how external macro factors are integrated into Smart City evaluations. Pira (2021) introduces a taxonomy for smart sustainable city indicators, Sharifi (2022) explores the nexus between Smart City indicators and disaster resilience, and Serrano et al. (2022) propose a framework for structuring Smart City KPIs.

Table 2: Overview of research paper and studies focused on evaluation of Smart Cities. Source: own processing.

Title	**Journal / Book / Conference**	**Reference**	**Summary of findings**
Smart cities ranking: An effective instrument for the positioning of the cities	ACE: Architecture, City and Environment	Giffinger and Gudrun (2010)	It introduces a Smart City ranking that is based on the list of characteristics and six smart factors (economy, people, governance, mobility, environment, living).
Definition methodology for the Smart Cities model	Energy	Lazaroiu and Roscia (2012)	It develops a model for computing the Smart City indexes, including assigned weights.
Smart Cities: Definitions, dimensions, performance, and initiatives	Journal of Urban Technology	Albino et al. (2015)	It identifies the main dimensions and elements characterizing a Smart City.
Smart city indicators: A systematic Literature Review	Journal of Telecommunication, Electronic and Computer Engineering	Purnomo and Prabowo (2016)	Conducts a systematic review of existing Smart City evaluation methods.
New key performance indicators for a smart sustainable city	Sustainability	Hara et al. (2016)	Proposes new KPIs specifically for sustainable Smart Cities.
Indicators and Actions for the Smart and Sustainable City: A Study on Italian Metropolitan Cities	Smart Planning: Sustainability and Mobility in the Age of Change	Battarra et al. (2018)	Explores the connection between indicators and actions cities can take to improve on them.
SMART CITY: Definition and evaluation of key performance indicators	2018 international conference and exposition on electrical and power engineering (EPE)	Picioroagă et al. (2018)	Focuses on defining KPIs for Smart Cities and proposes methods for evaluating them.

Title	Journal / Book / Conference	Reference	Summary of findings
Smart cities evaluation–a survey of performance and sustainability indicators.	44th Euromicro Conference on Software Engineering and Advanced Applications (SEAA)	Petrova-Antonova and Ilieva (2018)	Surveys the landscape of performance and sustainability indicators currently used in Smart City evaluations.
Indicators and Rating Systems for Sustainable Smart Cities	Green Planning for Cities and Communities: Novel Incisive Approaches to Sustainability	Dall'O' (2020)	Analyzes indicators and rating systems used specifically for sustainable Smart Cities.
Exploring the Smart City indexes and the role of macro factors for measuring cities' smartness	Social indicators research	Alderete (2020)	Investigates how existing indexes incorporate external factors (macro factors) that can influence a city's smartness.
A novel taxonomy of smart sustainable city indicators	Humanities and Social Sciences Communications	Pira (2021)	The results provide a set of indicators that allow both policymakers and researchers to evaluate the smartness and sustainability of their initiatives at the same time.
Smart city indicators: Towards exploring potential linkages to disaster resilience abilities	APN Science Bulletin	Sharifi (2022)	Explores the potential link between Smart City indicators and a city's ability to withstand and recover from disasters.
Smart cities and communities: A key performance indicators framework	National Institute of Standards and Technology Special Publication	Wollman et al. (2022)	Proposes a framework for organizing KPIs for Smart Cities.
Smart city indexes, criteria, indicators and rankings: An in-depth investigation and analysis	IET Smart Cities	Toh (2022)	Conducts an in-depth analysis of various Smart City evaluation methods, examining existing indexes, their criteria, indicators, and resulting rankings.
Measuring progress of smart cities: Indexing the smart city indices.	Urban Governance	Lai and Cole (2023)	Focuses on the integrity and quality of existing Smart City indices.

Title	Journal / Book / Conference	Reference	Summary of findings
Review of smart city assessment tools.	Smart Cities	Patrão et al. (2020)	Discusses the main gaps in current methodologies and suggests improvements for future tools. The review highlights the importance of Smart City Assessment in delivering performance indicators that monitor multiple benefits for various stakeholders, including city authorities, investors, researchers, and citizens.
Towards evaluation design for smart city development.	Journal of urban Design	Caird and Hallett (2019)	Discusses the challenges and considerations in evaluating Smart City initiatives. It emphasizes the need for robust evaluation designs that can accurately measure the performance and impact of Smart City projects.
A construction of smart city evaluation system based on cloud computing platform.	Evolutionary Intelligence	Wang et al. (2020)	Discusses the development of a Smart City evaluation system that leverages cloud computing technology. The paper presents an application-oriented cloud computing platform architecture designed to improve evaluation results and enhance the capacity of Smart Cities.
Research on smart city evaluation based on hierarchy of needs.	Procedia Computer Science	Zhang et al. (2019)	Explores the concept of Smart City evaluation through the lens of Maslow's hierarchy of needs. It proposes a novel framework for assessing Smart City initiatives by aligning them with the different levels of human needs, from basic physiological requirements to self-actualization.
Criteria for smart city identification: a systematic literature review.	Sustainability	Dashkevych and Portnov (2022)	A comprehensive review was conducted on the empirical criteria used to define and measure the smartness of cities. The authors identified a total of 48 metrics for Smart City identification, which they categorized into three main groups: economy and technology, environment, and society.

2.2.1 Structure of Smart City evaluation frameworks

Table 3 provides a comprehensive overview of the common categories used to evaluate and compare Smart Cities. It was organized into four main themes: Economy and Innovation,

Environment and Sustainability, Governance and Social Equity, and Infrastructure and Technology. Each theme includes several categories, such as Economic Performance, Renewable Energy and Efficiency, Citizen Engagement and Participation, and Transportation, with corresponding subcategories and specific indicators. For instance, under Governance and Social Equity, the category of Transparency and Accountability includes subcategories like Freedom of Information, Corruption Perception, and Rule of Law Index. This table serves as a valuable resource for understanding the multidimensional nature of Smart City valuation and the diverse categories involved in assessing the development and performance of Smart Cities.

The information for creating the table was gathered through a systematic search using various online resources. The search involved using keywords related to Smart City evaluation, such as "Smart City indicators," "Smart City performance," and "Smart City evaluation." The search was conducted on the resources listed in Table 1 and Table 2. The selected resources provided insights into different evaluation models, methodologies, and criteria for assessing Smart Cities. The information was then synthesized and organized into the table, ensuring it covers various evaluation categories and subcategories.

Table 3: Common categories in which Smart Cities can be evaluated and compared. Source: own processing.

Theme	**Dimension / category**	**Indicator / subcategory**
Economy and Innovation	Economic Performance	GDP growth rate, unemployment rate, productivity, foreign direct investment, export performance, income levels
	Knowledge and Innovation	Startup activity, R&D investment, patent applications, knowledge-based jobs, digital economy penetration, venture capital investment
	Entrepreneurship and Competitiveness	Number of new businesses, ease of doing business, global competitiveness ranking, World Bank Doing Business ranking
Environment and Sustainability	Renewable Energy and Efficiency	Share of renewable energy in total energy mix, energy consumption per capita, smart grid penetration, building energy efficiency
	Pollution and Waste Management	Air quality index, water quality index, greenhouse gas emissions per capita, waste recycling rate, landfill diversion rate

Theme	Dimension / category	Indicator / subcategory
	Urban Green Spaces and Sustainability	Percentage of green space per capita, biodiversity, urban agriculture, sustainable land use management
	Climate Change Adaptation and Resilience	Sea level rise risk, heat wave risk, flood risk, disaster preparedness score, adaptation strategies
Governance and Social Equity	Citizen Engagement and Participation	Number of e-government services, citizen satisfaction with government, public participation in decision-making, open data availability
	Transparency and Accountability	Freedom of information index, corruption perception index, rule of law index, government effectiveness
	Social Mobility and Equity	Income inequality, poverty rate, healthcare access, education levels, crime rates, access to technology
	Inclusivity and Accessibility	Accessibility for people with disabilities, gender equality index, ethnic diversity, access to public spaces
Infrastructure and Technology	Transportation	Public transportation usage, traffic congestion levels, e-mobility adoption, intelligent transportation systems
	ICT and Connectivity	Broadband penetration, mobile broadband speed, public Wi-Fi coverage, IoT adoption
	Smart Buildings and Infrastructure	Number of smart buildings, building energy management systems, smart grid adoption, renewable energy integration, waste management infrastructure
	Water Management	Water availability, water efficiency, non-revenue water, smart water meters
Health and Wellbeing	Healthcare Access and Quality	Life expectancy, mortality rate, infant mortality rate, number of hospital beds per capita, access to healthcare services
	Public Safety and Security	Crime rate, homicide rate, traffic accident rate, emergency response time, cybersecurity
	Air Quality and Pollution	Air quality index, noise pollution levels, green space coverage, pollution control measure

Theme	Dimension / category	Indicator / subcategory
Resilience and Disaster Management	Disaster Preparedness and Risk Management	Risk assessments, early warning systems, emergency response plans, evacuation procedures, disaster recovery plans
	Infrastructure Resilience	Vulnerability of critical infrastructure, redundancy of systems, cybersecurity measures
	Social Cohesion and Community Resilience	Level of social trust, community organizations, volunteering rates, disaster preparedness among citizens

2.2.2 Indicators and rating systems

Table 4 shows six indicators and rating systems for Smart Cities, which are smart economy, smart people, smart governance, smart environment, smart mobility, and smart living. It is based on the Smart City ranking developed by Giffinger and Gudrun (2010). Each indicator has a definition, a set of categories, an evaluation method, and a comparison criterion. Each indicator is defined by specific categories, such as innovation, entrepreneurship, productivity, competitiveness, education, skills, diversity, social inclusion, participation, transparency, energy, climate, pollution, transport, infrastructure, accessibility, health, safety, culture, and quality of life. This table offers a comprehensive overview of the various indicators that contribute to a Smart City.

Table 4: Indicators used to evaluate the development of Smart Cities. Source: own processing.

Indicator	Categories	Definition	Evaluation	Comparison
Smart economy	Innovation, entrepreneurship, productivity, competitiveness, etc.	The ability of a city to foster economic growth and development using ICT, knowledge, and creativity.	Based on subcategories such as patents, start-ups, GDP, employment, etc.	Compare the economic performance and potential of different cities.
Smart people	Education, skills, diversity, social inclusion, etc.	A city's human capital and social capital reflect its citizens' education, skills, diversity, and social inclusion.	Based on subcategories such as literacy, enrollment, qualifications, migration, participation, etc.	Compare the human and social assets and challenges of different cities.

Indicator	Categories	Definition	Evaluation	Comparison
Smart governance	Participation, transparency, accountability, efficiency, etc.	The quality and effectiveness of the public administration and services in a city, as well as the degree of citizen involvement and empowerment.	Based on subcategories such as e-government, public satisfaction, corruption, civic engagement, etc.,	Compare the governance practices and outcomes of different cities.
Smart environment	Energy, climate, pollution, natural resources, etc.	The environmental sustainability and resilience of a city reflect its impact and adaptation to environmental changes and challenges.	Based on subcategories such as energy consumption, greenhouse gas emissions, air quality, waste management, green spaces, etc.	Compare the environmental performance and risks of different cities.
Smart mobility	Transport, infrastructure, accessibility, connectivity, etc.	The accessibility and efficiency of transport and communication systems in a city, as well as the degree of connectivity and integration of its networks.	Based on subcategories such as modal share, congestion, travel time, broadband coverage, ICT usage, etc.	Compare the mobility and connectivity options and levels of different cities.
Smart living	Health, safety, culture, leisure, quality of life, etc.	The well-being and satisfaction of citizens in a city, reflecting their health, safety, culture, leisure, and quality of life.	Based on subcategories such as life expectancy, mortality, crime, cultural events, happiness, etc.	Compare the living standards and conditions of different cities.

3 DATA ANALYSIS AND COMPARISON OF SELECTED CITIES

3.1 RESEARCH METHODOLOGY AND DESIGN

First, considering the findings resulted from the previous section, it was decided that data analysis and comparison of selected cities will be performed using secondary data sources. A secondary data collection approach was employed to analyse and compare countries, aiming to achieve the stated objective of this thesis. Secondary data collection involves gathering information that already exists, rather than collecting it firsthand. Typically, such data originate from distinct sources and are subsequently made publicly accessible. In essence, secondary data refer to information previously acquired by another party. Related steps and concrete sources are described in the next section.

Then, a list of the most representative Smart Cities was created aiming to select the cities that can provide data and best practices for data analysis. A comparative analysis that encompasses indicators used to evaluate the development of Smart Cities, see Table 4, was performed to identify similarities and differences across these indicators. Finally, results are presented, and the most important findings are discussed.

3.1.1 Research instrument and data collection

Systematic search, content and comparative analyses were used as a research instrument for this thesis. Data were collected from freely available resources on Smart Cities indexes and reports and were complemented by other city-related resources such as Smart City strategies or websites on which relevant information for analysis of a concrete Smart City can be found. It should be also noted that some of editions of indexes are paid, so they cannot be used in the analysis of Smart Cities. Thus, the latest editions of five indexes presented in Table 1 were used as sources, i.e., CIMI 2022 – Berrone and Ricart (2022), GCI 2023 – Kearney (2023), GPCI 2023 – Mori Memorial Foundation (2023), SCG 2021 – Eden Strategy Institute (2021), and SCI 2023 – IMD Business School (2023).

3.1.2 Selection of cities and objectives of the analysis

An approach that focuses on the best-performing Smart Cities was applied for the selection of cities. By doing so, important insights from their accomplishments, enhancements, and best practices can be gained. Also, this approach can offer recommendations to Smart Cities that are currently falling behind in specific dimensions and indicators. A sample of representative cities

for analysis was selected based on the current report for CIMI 2022. During the review of the literature and other sources, several of them referred to this very index. Also, this index covers the highest number of Smart Cities from all indexes.

The first 20 best cities from the CIMI 2022 index were selected and supplemented with other indexes and corresponding rankings to ensure that the sample will include only the top performed Smart Cities. Then, the best Smart Cities were selected for more detailed analysis – these cities are highlighted in bold italics in Table 5. There were two conditions that limited the selection of the sample of cities: 1) a city must be included in at least 4 different indexes to have enough information sources (available reports) for the analysis, and 2) a maximum of 2 cities could be selected from one country. This resulted in a sample consisting of 14 Smart Cities.

Also, the average rank was calculated for the cities in Table 5. To calculate the average rank for the cities, the following steps was followed:

1. Add up the ranks for each city across all the indexes.
2. Count the number of indexes each city is ranked in.
3. Divide the total rank by the number of indexes to get the average rank for each city.

The calculation was repeated for each city to determine their average ranks. It was found that the ranks for respective cities differ significantly, e.g., Singapore has the average rank 5.40, which is the second-best average rank after London. These findings thus confirm our previous decision to include 5 indexes and corresponding reports in the analysis, because by selecting only one index, the analysis could omit some important findings included in other sources.

Table 5: Selection of the sample of Smart Cities. Source: own processing.

Smart City–Country	**Latest editions of selected indexes and respective ranks**					
	CIMI 2022	**GCI 2023**	**GPCI 2023**	**SCG 2021**	**SCI 2023**	**Average rank**
London–United Kingdom	***1***	***2***	***1***	***3***	***6***	**2.60**
New York–USA	***2***	***1***	***2***	***6***	***21***	**6.40**
Paris–France	***3***	***3***	***4***	***-***	***46***	**14.00**
Tokyo–Japan	***4***	***4***	***3***	***22***	***72***	**21.00**
Berlin–Germany	***5***	***16***	***10***	***23***	***33***	**17.40**
Washington–USA	***6***	***19***	***36***	***-***	***39***	**25.00**

Smart City–Country	Latest editions of selected indexes and respective ranks					
	CIMI 2022	GCI 2023	GPCI 2023	SCG 2021	SCI 2023	Average rank
Singapore–Singapore	***7***	***7***	***5***	***1***	***7***	**5.40**
Amsterdam–Netherlands	***8***	***20***	***6***	***10***	***15***	**11.80**
Oslo–Norway	9	-	-	27	2	**12.67**
Copenhagen–Denmark	***10***	***-***	***11***	***35***	***4***	**15.00**
Munich–Germany	11	-	-	-	20	**15.50**
Seoul–South Korea	***12***	***14***	***7***	***2***	***16***	**10.20**
Chicago–USA	13	11	25	42	61	**30.40**
Zurich–Switzerland	***14***	***-***	***19***	***45***	***1***	**19.75**
Vienna–Austria	***15***	***29***	***13***	***9***	***28***	**18.80**
San Francisco–USA	16	17	27	13	68	**28.20**
Hamburg–Germany	17	-	-	-	11	**14.00**
Dublin–Ireland	***18***	***-***	***28***	***26***	***63***	**33.75**
Rotterdam–Netherlands	19	-	-	47	41	**35.67**
Helsinki–Finland	***20***	***-***	***31***	***5***	***8***	**16.00**

3.2 ANALYSIS OF SMART CITIES

Each city is analysed in accordance with the indicators used to evaluate the development of Smart Cities presented in Table 4, i.e., smart economy, smart people, smart governance, smart environment, smart mobility, and smart living. Information for analyses in the context of these indicators were gathered from sources listed in chapter 3.1.1.

3.2.1 London

London is included in all latest editions of selected indexes and has an average rank of 2.6. In 2018, the city launched the *Smarter London Together* project, which is intended to serve as a flexible digital master plan for making London the smartest city in the world. According to the *CIMI 2022*, London tops the overall ranking thanks to its performance in the dimensions of human capital (rank #1), international profile (#1), urban planning (#1), governance (#2), and

mobility and transportation (#4). However, the city does not perform as well in the dimensions of social cohesion (rank #25) and environment (#17).

Smart Economy – it focuses on new digital platforms to increase transparency or boost the sharing economy. Its strengths are driven by its cultural attractions. It hosts more start-ups than any other city in the world and the number of international meetings held in the city.

Smart People – London is one of the megacities, i.e., those with a population of over 10 million. It has the largest number of top-level business schools and the largest number of universities in the world's top 500. Its strategy Smarter London Together focuses on improving digital skills.

Smart Governance – promote transparency, empower citizens, fight corruption, and harness new technologies to strengthen governance; address digital inclusion, data innovation, technology adoption, and digital leadership.

Smart Environment – sensors that create data in new ways to combat the causes and effects of pollution and climate change, be better connected and open to new technologies in the built environment.

Smart Mobility – it has many electric car charging stations, its AI projects, and its infrastructure, with many buildings and high-rises and a very advanced system for bicycle rental/shared use. It also has the highest number of airline passengers, which is consistent with its status as the city with the largest number of air routes.

Smart Living – focuses on personal well-being, air quality and public health campaigns to improve living, it also supports digitalization of all processes to provide more current information about the housing fund.

3.2.2 New York

New York is included in all latest editions of selected indexes and has an average rank of 6.4. In 2021, the Mayor's Office of the Chief Technology Officer (NYC CTO) released the New York City Internet of Things Strategy which aims to develop a *Rapid IoT program* to allow agencies to deploy short-term, low-cost IoT solutions to gather data and improve city services.

According to *GCI 2023*, New York ranked highest in human capital. In *GPCI 2023*, the city ranked highest in economy (371.1) and research and development (R&D) (206.5). In R&D, the common strength of New York and other top cities in United States (Los Angeles, Boston, San

Francisco and Chicago) are present in expenditure and winners of prizes in science and technology. The city also ranked second after London in cultural interaction (259.4).

In *CIMI 2022*, the city was second in overall ranking. The city was highest in economy (#1) and mobility and transportation, ranked (#2) in urban planning, (#3) in human capital and international profile, and (#6) in technology. Performed poorly in social cohesion (#121) and environment (#105).

Smart Economy: New York leverages technology and data to create a more efficient, sustainable, and equitable economic system. The city boasts a thriving tech scene with a concentration of startups, venture capitalists, and established tech companies. This fosters innovation in areas like AI, IoT, and big data, all crucial for a smart economy. The city has a strong commitment to sustainability, evident in initiatives like *LinkNYC kiosks* (providing free Wi-Fi with data collection for better resource management) and the *NYC Energy Conservation Code* (promoting energy-efficient buildings). These efforts contribute to a greener and more resilient smart economy.

Smart People: A population of over 8 million with a highly educated population, top-level universities and business schools, and a commitment to improving digital skills and promoting smart people through programs like *NYC Smart City Testbed* Program. This allows city agencies to collaborate with companies and academic institutions on pilot projects that operate in public space. The program provides a new way to pilot emerging technologies, allowing the city to make more informed decisions about the best technologies and how to use them. The city is also investing in climate technology and promoting sustainable urban development, making it a hub for innovation and progress.

Smart Governance: Focused on addressing digital inclusion, data innovation, technology adoption, and digital leadership. One of the key initiatives is the *NYC Open Data Portal*, which provides access to over 2,500 datasets from city agencies, allowing citizens to access information on everything from crime statistics to building permits. The portal is designed to promote transparency and empower citizens to participate in the decision-making process.

Smart Environment: Deployment of smart sensors throughout the city to monitor air quality, noise levels, and other environmental factors. These sensors provide real-time data that can be used to identify pollution hotspots, track emissions, and inform policy decisions to improve air quality and reduce environmental impact.

Smart Mobility: Improving transportation and reducing congestion through the Midtown in Motion program, which uses sensors, cameras, and vehicle pass readers to monitor traffic and adjust traffic signals in real-time to improve the flow of traffic and reduce emissions from idling vehicles.

Smart Living: Working on reducing air pollution through various strategies, such as the 80 × 50 strategy, which aims to reduce greenhouse gas emissions by 80% by 2050. This strategy is expected to have significant public health benefits, including the reduction of premature deaths, hospitalizations, and emergency department visits for respiratory conditions.

3.2.3 Paris

Paris has a population of over 11 million and is included in four latest editions of selected indexes except SCG 2021 and has an average rank of 14. The city has a strong commitment to innovation and sustainability. The city has embarked on the *Paris Smart City 2050* project, which aims to transform Paris into a model for sustainable urban living. The project includes the development of eight prototypes of energy-plus towers, which are designed to produce more energy than they consume. These towers are intended to combat the urban heat-island effect, increase urban density, and integrate nature into the cityscape.

According to *CIMI 2022*, Paris was one of the top performing cities, thanks to its performance in the dimensions of International profile (#2), Mobility and transportation (#3), human capital (#5) and economy (#9). However, the city does not perform well in the dimensions of social cohesion (#67), governance (#17), and technology (#27). *In GCI 2023*, had the overall performance in information exchange. While in *GPCI 2023*, the city was the ranked highest in Livability (390) and ranked third in cultural interaction (250.7).

Smart Economy: Implementing new economic models and prioritizing innovation and research. The city's strategic plan, "*Paris Smart and Sustainable Looking ahead to 2020 and beyond*" highlights the importance of digital technology in driving economic growth and sustainability. The plan aims to make Paris a city that is not only smart and sustainable but also open, connected, and inventive.

Smart People: Active, inclusive, sustainable, and intelligent citizenship. The city offers equal opportunities to all, considering the needs of individuals.

Smart Governance: Encourages citizen intervention and the use of new digital technologies for decision-making. The city's strategic plan emphasizes the importance of open data in

creating new services that facilitate the lives of citizens and encourage them to participate in city life.

Smart Environment: Management of natural resources and the use of new technologies for electricity production. The city aims to reduce greenhouse gas emissions by 2050, in line with the *Paris Climate-Air-Energy Action Plan Towards a Carbon Neutral City And 100% Renewable Energies.* The development of energy-plus towers is one of the initiatives aimed at combating the urban heat-island effect, increasing urban density, and integrating nature into the cityscape.

Smart Mobility: Prioritizing modern, sustainable, and comprehensive transportation solutions such as promoting cycling and pedestrian infrastructure, boasting an extensive network of bike lanes, car-free zones, and pedestrian walkways. The city is transitioning its public transportation fleet to electric vehicles, including buses, trams, and car-sharing services. This shift not only reduces emissions but also contributes to a quieter and more pleasant urban environment while also adopting dockless e-scooters and e-bikes as popular modes of transportation.

Smart Living: Focuses on the quality of life of citizens, with a focus on health, safety, easily accessible services, housing for all, the presence of schools and universities, social cohesion, and tourist attractiveness.

3.2.4 Tokyo

Tokyo is included in all latest editions of selected indexes and has an average rank of 21. With a population of over 30 million, the city has a forward-thinking approach to urban development which is evident in its Smart City Tokyo initiatives, which have earned it a commendable 3.007 Smart Points rating. Tokyo has been actively engaged in the Society 5.0 initiatives, prioritizing the installation of Smart Cities to address social and economic challenges related to mobility, health, tourism, energy, environment, and finance.

In *GPCI 2023*, the city has been closely trailed by #4 Paris since last year, maintained its #3 position in the comprehensive ranking by a narrow margin. This year Tokyo improved in the livability #3 (367.7), research and development #4 (143.4), accessibility #8 (183.3) and in cultural interaction #5 (237.5). While in *CIMI 2022*, the city ranked #4 in overall ranking. The city performed quite well in dimensions such as economy #2, international profile #6, technology #9, governance #9, and human capital #10. However, there was low performance in social cohesion #41, environment #25, and urban planning #112.

Smart Economy: Focusing on leveraging cutting-edge technologies and fostering entrepreneurship to drive sustainable growth and competitiveness. Tokyo's strategic approach includes attracting foreign businesses in fintech, IoT, and related fields, issuing green bonds to advance environmental policies, and revitalizing the financial industry to restore its position as Asia's leading global financial city.

Smart People: Prioritizes creating a vibrant and inclusive city where everyone can lead active and fulfilling lives. The city's smart people initiatives focus on enhancing healthcare, promoting healthy living, supporting the disabled, advancing the active role of women in society, and promoting the employment of senior citizens. There are efforts to provide seamless support from pregnancy to parenting, expand childcare options, and enhance support for families in nurturing a diverse and thriving community.

Smart Governance: Creates a transparent, efficient, and responsive government that leverages technology to enhance public services. The city has implemented the Digital Procedure Law to accelerate the digitalization of administrative procedures, laying the groundwork for promoting Smart Cities. The establishment of the Smart City Institute Japan demonstrates Tokyo's commitment to fostering collaboration and innovation in the Smart City domain, providing a platform for public, private, and social sector organizations engaged in the city development.

Smart Environment: Creating an environmentally friendly and sustainable urban environment. The city's smart environment initiatives focus on promoting energy efficiency, reducing food loss and waste, and advancing eco-friendly practices. The city’s efforts to spread the use of LED lights, promote energy-saving measures, and encourage the use of hydrogen for energy production highlight its commitment to building a smart energy city and reducing environmental impact.

Smart Mobility: Revolutionizing transportation, reduce congestion, and improve connectivity. The city has an advanced public transportation system, including subways, buses, and trains, that runs efficiently and effectively. Tokyo has also implemented intelligent transportation systems, such as smart traffic lights and route optimization algorithms, to minimize traffic congestion and enhance the overall mobility experience for residents and visitors.

Smart Living: Envisions a smart living environment that is safe, inclusive, and sustainable. The city's smart living initiatives focus on creating a comfortable and resilient urban environment where residents can feel close to nature. There are efforts to enhance healthcare,

encourage healthy living, and support diverse communities underscore its commitment to fostering a vibrant and livable city for all its residents.

3.2.5 Berlin

Berlin is included in all latest editions of selected indexes and has an average rank of 17.4. The city has been actively working on implementing Smart City strategies to improve the quality of life for its residents and enhance its competitiveness. The Smart City strategy is supported by a robust and inclusive governance structure, including the Smart City Unit & Office, the Political Board Smart City, the Smart City Network, and the Smart City Lab. These entities bring together a variety of public and private stakeholders to communicate directly with policymakers and contribute to the development of Smart City initiatives.

According to *CIMI 2022*, Berlin ranked #5 in overall performance due to its performance in these dimensions: governance #3, urban planning #5, human capital #7 and mobility and transportation #7. However, it didn't perform so well in international profile #14 and environment 21#; performed poorly in technology 39#, social cohesion #40, and economy #94. While in *GPCI 2023*, it was one of the top performing cities in livability (359.3).

Smart Economy: Focused on creating a sustainable, livable, and connected city that attracts businesses and fosters innovation. The city has already achieved several notable achievements, including being named the *Greenest City in Europe* by the European Union in 2019, reducing carbon emissions by 43% compared to 1990 levels, and ranking as the third-best startup city in the world.

Smart People: Enhancing the quality of life for its residents. The city has implemented measures to improve healthcare, support the disabled, and promote work-life balance. The city offers programs to enhance education and skills development, such as the Berlin University Alliance.

Smart Governance: Create a transparent and efficient government that leverages technology to enhance public services. The city has established a robust and inclusive governance structure, including the Smart City Unit, the Smart City Network, and the CityLAB. These entities facilitate collaboration between public and private stakeholders, ensuring that policymakers are directly engaged with the city's Smart City initiatives.

Smart Environment: Reducing the use of finite resources, establishing the use of renewable energies, increasing resource efficiency and the climate neutrality of Berlin by the year 2050,

and minimizing the negative side-effects of living in a densely populated urban environment. The city has implemented several measures to improve energy efficiency, such as mandatory energy audits for large buildings and subsidies for energy-efficient renovations.

Smart Mobility: Improving mobility and reducing carbon emissions. The city has launched several projects to enhance mobility, including a smart parking system that uses sensors to detect available parking spaces and a digital platform that integrates public transportation.

Smart Living: Developing the international competitiveness of the capital city region of Berlin-Brandenburg, increasing economic strength and value creation, and improving the quality of life for citizens.

3.2.6 Washington

Washington is included in four latest editions of selected indexes, *SCG 2021* being the exception and has an average rank of 25. The city has launched various programs to bridge the digital divide, such as providing free public Wi-Fi, offering digital literacy training, and supporting the deployment of broadband infrastructure in underserved communities while also investing in intelligent transportation systems (ITS) to reduce congestion, improve safety, and minimize the environmental impact of transportation in the city.

According to *CIMI 2022*, the city ranked 6th overall. The city ranked #4 in human capital, #7 in technology, #8 in governance and #9th in urban planning. It performed fairly in economy #11 and poorly in social cohesion #73, environment #131, and international profile #41.

Smart Economy: The city is investing in technology and digital infrastructure to support businesses and startups. Initiatives such as innovation hubs, business incubators, and support programs for small businesses are part of its smart economy strategy.

Smart People: Enhancing the quality of life for its residents by investing in education, healthcare, and social services. Offers programs and resources to ensure everyone has the technology and training needed to participate in the digital economy.

Smart Governance: The city is leveraging technology to enhance public services, streamline administrative processes, and promote open data initiatives.

Smart Environment: Focusing on sustainability and environmental conservation as part of its Smart City initiatives. The city is implementing measures to reduce carbon emissions, promote energy efficiency, and enhance waste management practices.

Smart Mobility: Working to improve transportation systems by utilizing real-time data and traffic management systems to optimize traffic flow, reduce congestion, and improve overall travel times. The city is investing in smart transportation solutions, such as intelligent traffic management systems, bike-sharing programs, and electric vehicle infrastructure. Dockless e-scooters and e-bikes are becoming increasingly popular in the city.

Smart Living: Exploring ways to use technology to connect residents, strengthen neighbourhood ties, and foster a more vibrant sense of community. Focusing on enhancing healthcare services, affordable housing, community development, promoting healthy lifestyles, and fostering social inclusion.

3.2.7 Singapore

Singapore is included in all latest editions of selected indexes and has an average rank of 5.4. The city recently launched the Smart City Technology division (SCTD), a capability centre for designing, building, and implementing a government wide IoT infrastructure. Renamed and reorganized in January 2023, SCTD focuses on developing technologies, capabilities, and products for Singapore's Smart City vision. Its work spans hardware design to cloud management platforms, with projects like the *Personal Alert Button* and *Open Digital Platform*. SCTD collaborates with industry, research entities, and agencies to build IoT capabilities, pilot new sensor technologies, and tackle IoT challenges.

According to *SCG 2021*, Singapore tops the overall ranking due to the introduction of its Smart Nation Singapore strategy in 2014, through which has helped the city-state launch a series of strategic projects across all aspects of urban life, from urban mobility to e-payments and a government portal unified by a single ID, helping them become a Smart City. In *CIMI 2022*, the city was ranked #7, preforming well in the dimensions of international profile #4 and technology #4. However, the city does not perform as well in other dimensions such as, Economy#20, Human capital #40, Social cohesion #31, Environment #78, Governance #24, Urban Planning #26, and Mobility and transportation #58.

Although for economy dimension, the performance of Singapore is quite different in *GPCI 2023*. The city ranked #4 in economy (308.3) dimension in this index; certain indicator groups (Market Size, Market Attractiveness, Economic Vitality, Human Capital, Business Environment, and Ease of Doing Business) and indicators (Nominal GDP, GDP per Capita, GDP Growth Rate, Economic Freedom, Stock Market Capitalization, World's Top 500

Companies, Total Employment, Employees in Business Support Services, Wage Level, Availability of Skilled Human Resources, Variety of Workplace Options, Corporate Tax Rate, Political, Economic and Business Risk) must have been present here that were not present in *CIMI 2022* which caused a significant difference in both indexes.

Smart Economy: The city-state has established itself as a global financial hub and a centre for technological advancement. Committed to creating a digitally powered city has led to the introduction of various smart technologies in both the public and private sectors, fostering a dynamic ecosystem for startups and businesses to thrive.

Smart People: Prioritizes education and skills development to ensure its population is equipped for the digital age. Invests in lifelong learning programs and initiatives to upskill its workforce, promoting a culture of continuous learning and innovation. Emphasizes on developing human capital with its goal of creating a digitally ready population that can proactively contribute to the city's smart initiatives.

Smart Governance: Efficient and transparent governance, leveraging technology to enhance public services and citizen engagement. Implemented digital solutions for various government services, promoting accessibility and efficiency. Singaporeans can access a range of government services, provide feedback, and receive personalized information based on their location and interests.

Smart Environment: Committed to sustainability and environmental conservation despite its limited land area. Implemented green initiatives such as water recycling systems, green building standards, and urban green spaces to enhance environmental sustainability. Focus on sustainable mobility, highlighted by investments in public transport infrastructure and sustainable transportation options.

Smart Mobility: Prioritizes smart mobility solutions to improve transportation efficiency and reduce congestion. Implemented intelligent transportation systems, autonomous vehicles, and smart traffic management technologies to enhance mobility for its residents. Initiatives like the *Smart Urban Mobility program* focus on optimizing transport efficiency and accessibility, ensuring that residents have convenient and sustainable transportation options.

Smart Living: Offers a high quality of life for its residents, supported by initiatives that focus on safety, healthcare, education, and cultural amenities. Provides a range of smart living

solutions, including smart homes, digital healthcare services, and Smart City applications, to enhance the overall well-being and convenience of its residents/citizens.

3.2.8 Amsterdam

Amsterdam is included in all latest editions of selected indexes and has an average rank of 11.8. In 2016, Amsterdam was awarded Europe's Capital of Innovation by the European Commission. The city is a leader in circular economy (a Smart City strategy) initiatives, with programs such as the *Amsterdam Smart City Circular Challenge*, which encourages startups and entrepreneurs to develop innovative solutions for waste reduction and resource management. The city also has a strong focus on citizen participation and engagement, with initiatives such as the *Amsterdam Smart City Lab*, which provides a platform for citizens to co-create and test new Smart City solutions. The city has also established an innovation district called *Amsterdam Science Park*, which is home to several research institutions and high-tech companies.

In *GPCI 2023*, Amsterdam ranked highest in accessibility #1 (229.2) and performed fairly in livability #8, Economy #12, cultural interaction #15, environment #17, and research and development #19. While in the *CIMI 2022*, the city performed fairly in technology #10, urban planning #13, and environment #14. However, there was poor performance in international profile #18, mobility and transportation #20, human capital #35, economy #38, governance #40, and social cohesion #48. The difference in the economy ranking between the two indexes is significant, with Amsterdam ranking much higher in the GPCI 2023. This is likely due to the inclusion of various indicator groups and indicators in the GPCI 2023 that are not present in the CIMI 2022 as previously stated.

Smart Economy: Thrives on innovation and sustainability. Fosters an environment where businesses, government, and academia work together to drive economic growth through technology. Initiatives like the *Amsterdam Economic Board* and *Amsterdam Smart City* focus on transitioning from fossil fuels to renewable energy, promoting circular economy practices, and supporting startups and scaleups in high-tech industries.

Smart People: Focus on education, digital literacy, and community engagement ensures that its residents are well-equipped to thrive in a digital society. Encourages citizen participation in urban development and leverages a network of innovators and changemakers to co-create Smart City solutions.

Smart Governance: Emphasizes transparency, collaboration, and citizen involvement. The city has appointed a Chief Technology Officer to oversee data-driven city management and Smart City initiatives. This approach has led to the development of projects that involve stakeholders from both the public and private sectors, aiming to improve city services and policymaking through data analytics.

Smart Environment: Sustainability is a key pillar of Amsterdam's Smart City strategy. The city has ambitious goals to reduce carbon emissions, increase renewable energy usage, and improve air and water quality. Projects like the *Amsterdam Circular 2020-2025 Strategy* aim to transform the city into a circular one, where waste is minimized, and resources are reused efficiently.

Smart Mobility: Redefining urban mobility with a focus on accessibility, sustainability, and innovation. The *Program Smart Mobility Amsterdam 2019-2025* seeks to provide cleaner and more efficient transportation options, such as shared electric vehicles and smart traffic management systems, to reduce pollution and congestion.

Smart Living: Committed to improving the quality of life for its residents. Integrates cutting-edge solutions to create a more livable and innovative urban environment. This includes fostering a startup ecosystem, piloting autonomous vehicles, and engaging citizens in the co-creation of Smart City solutions.

3.2.9 Copenhagen

Copenhagen is included in four latest editions of selected indexes except *GCI 2023* and has an average rank of 15. The city has achieved a 42% reduction in carbon emissions since 2005 while experiencing a 25% growth in its economy, showcasing its commitment to both environmental sustainability and economic prosperity. Its Smart City initiatives focus on sustainable energy, digital innovation, and smart mobility. The city's EnergyLab Nordhavn project is a prime example of its innovative approach to smart energy systems. This five-year project, launched in 2014, bringing together academia, the city government, private companies, and the Danish national government to create a full-scale smart energy laboratory with district heating and smart-grid integration.

According to *CIMI 2022*, Copenhagen was one of the top performing cities in environment #3 and Social cohesion #4. It performed fairly in Governance #20, Technology #22, Urban planning #23, and International profile #25. Poorly in Mobility and transportation #31, Human

capital #45, and Economy #46. While in *GPCI 2023*, the city ranked #2 in environment (224.2); the close ranking highlights its commitment to environmental sustainability.

Smart Economy: Attracts clean technology companies, research institutions, and investors, fostering the development of solutions for renewable energy, energy efficiency, and sustainable resource management. Focus on sustainability and supports the growth of the green economy, creating jobs in clean technology and sustainable construction.

Smart People: Emphasizes sustainability principles. The city integrates sustainability education into school curriculums and encourages lifelong learning opportunities to equip and empower citizens to participate actively in shaping the city. Prioritizes social inclusion and equal opportunities to address social inequalities and ensure everyone can benefit from Smart City advancements.

Smart Governance: Utilizes data analytics and strives to deliver citizen-centric services. Data collected from sensors and citizen feedback enables targeted interventions and optimizes resource allocation. The city government prioritizes transparency and collaboration.

Smart Environment: Invests heavily in renewable energy sources like wind and solar power, promotes energy-efficient buildings, and incentivizes sustainable transportation options. Embraces the circular economy model, aiming to minimize waste and maximize resource reuse (recycling, upcycling, and converting waste into new products and energy).

Smart Mobility: Prioritizes dedicated bike lanes, safe intersections, and bike parking facilities, making cycling a convenient and safe way to get around. Incentivizes electric vehicle use, implements smart traffic management systems, and invests in shared mobility solutions.

Smart Living: Offers safe neighbourhoods, accessible healthcare, excellent education systems, and a vibrant cultural scene. Encourages the development of smart homes equipped with energy-efficient appliances and technologies that enhance comfort, security, and convenience for residents.

3.2.10 Seoul

Seoul is included in all latest editions of selected indexes and has an average rank of 10.2. In 2013, Seoul Metropolitan Government (SMG) launched the *Owl Bus* Night services after analysing vast amounts of mobile call logs and taxi ride data to optimize bus routes for late-night commuters. SMG has committed to installing 50,000 IoT sensors by 2022, supported by

a Smart City budget of USD 370 million. These sensors, known as *City life sensors*, collect data on various urban elements like noise, fine dust, night light intensity, and traffic. The Integrated Public Big Data Storage system processes this data using artificial intelligence to inform policy decisions and initiatives addressing urban challenges such as citizen safety and congestion.

According to *CIMI 2022*, Seoul ranked #6 in Governance and #8 in human capital. It performed fairly in International profile #19, Economy #21, Urban planning #22, and technology #25. Performed poorly in Mobility and transportation #41, Social cohesion #68, and environment #76.

Smart Economy: Leverages big data analytics to inform economic policies. By analysing data on consumer trends, traffic flows, and resource allocation, the city can invest in growth areas, optimize resource allocation, and create a more data-driven business environment.

Smart People: Prioritizes continuous learning and skill development. Actively promotes digital literacy for all residents. Training programs and initiatives bridge the digital divide, ensuring everyone can access and utilize technology effectively.

Smart Governance: The city government publishes datasets on various topics, allowing citizens and businesses to develop innovative solutions and hold authorities accountable. Encourages citizen participation in decision-making and have access to permits, pay fees, and communicate with authorities electronically, streamlining processes and improving efficiency.

Smart Environment: Implements air quality monitoring systems, promotes green transportation options, and incentivizes energy-efficient buildings to improve air quality. Developing a smart grid system which utilizes technology to optimize energy distribution and consumption, reducing overall energy use and promoting efficient energy utilization.

Smart Mobility: Extensive and efficient public transportation network. Buses, subways, and light rail systems connect various city districts, reducing reliance on private vehicles and encourages sustainable transportation choices.

Smart Living: Prioritizes public safety. The city utilizes camera surveillance systems, implements public safety initiatives, and invests in advanced emergency response systems to ensure a safe and secure environment for residents. Encourages the development of smart homes equipped with energy-efficient appliances, security systems, and home automation technologies that enhance comfort, convenience, and safety for residents.

3.2.11 Zurich

Zurich is included in four latest editions of selected indexes except *GCI 2023* and has an average rank of 10.75. Since 2008, the city has committed to reducing its energy consumption to 2,000 watts per person by 2050, with a focus on improving energy efficiency and renewable energy usage, sustainable buildings, promoting efficient modes of transportation, increasing public awareness, and promoting sustainable consumption.

In *GPCI 2023,* the city ranked 4th in economy while in *CIMI 2022* it ranked #21 in economy which is likely due to the inclusion of various indicator groups and indicators in the *GPCI 2023* that are not present in the *CIMI 2022* as previously stated in Amsterdam and Singapore. Zurich ranked #6 in governance and #8 in human capital in *CIMI 2022*. It performed fairly in urban planning #22, international profile #19, and technology #25. Poorly in social cohesion #68, environment #76, mobility and transportation #41.

Smart Economy: Focus on promoting economic growth, digital transformation, sustainability, and innovation. The city is home to a thriving financial sector and a growing tech industry, with several startups and innovation hubs.

Smart People: Promote equal opportunities and high quality of life for everyone. The city is committed to involving the entire population, including residents, workers, and visitors, in the development of the Smart City. Focus on education, skills development, and digital literacy, and promoting citizen participation and engagement in the city's decision-making processes.

Smart Governance: Promote transparency, accountability, and collaboration in the city's governance processes. Focus on open data, digital democracy, and participatory budgeting, and promoting collaboration between the city's administration, businesses, and citizens.

Smart Environment: Promote sustainability and environmental conservation. The city has set ambitious targets for reducing carbon emissions, increasing renewable energy production, and improving air and water quality. Focus on sustainable transportation, green buildings, and waste reduction.

Smart Mobility: Enable and test new solutions for attractive, resource-sparing, and space-efficient transportation solutions for all, including both passenger and freight transportation. The city has a well-developed public transportation system, with a focus on promoting sustainable transportation modes such as walking, cycling, and public transportation.

Smart Living: Promote a high quality of life for the city's residents. Focus on promoting healthy lifestyles, accessible and affordable housing, and community engagement.

3.2.12 Vienna

Vienna is included in all latest editions of selected indexes and has an average rank of 18.8. Vienna has committed to a strategic roadmap that will run from 2019 to 2050, with a headline goal of reducing CO2 emissions by 80 percent of 1990 levels by 2050. Vienna now has its citizen-owned solar power plant which was a government-led initiative that partnered with energy providers to redistribute ownership of energy production into the hands of its citizens. By 2017, sufficient solar power had been generated to power approximately 300,000 households.

In *GPCI 2023*, the city ranked #5 in livability and #5 environment. While in *CIMI 2022*, the city ranked #8 in mobility and transportation, #11 in urban planning, #11 environment, #20 international profile, #22 governance. Performed poorly in #77 economy, #34 human capital, and #83 social cohesion. The difference in environment is likely due to the inclusion of various indicator groups and indicators in the *GPCI 2023* that are not present in the *CIMI 2022*.

Smart Economy: Focused on promoting innovation, education, and entrepreneurship to create a stronger economy. The city aims to become a world-renowned centre for education and research activities, attracting new research units and researchers, and fostering the growth of new businesses.

Smart People: Focused on creating equal opportunities and a high quality of life for all residents. Working to strengthen comprehensive and integrated education services, encourage the uptake of voluntary higher education which would be accessible to all residents.

Smart Governance: Promoting transparency, collaboration, and citizen participation in city governance. Adopted a collaborative approach to decision-making, involving businesses, research institutes, public servants, and private citizens. Vienna's Smart City Framework Strategy 2019-2050 includes a goal to maintain the proportion of green space in the metropolitan area and reduce CO2 emissions in the transport sector.

Smart Environment: Focused on promoting resource efficiency and reducing greenhouse gas emissions. The city has set ambitious targets for renewable energy generation, energy efficiency, and climate change mitigation.

Smart Mobility: Focused on promoting eco-friendly mobility, renewable energy, and efficient use of resources. The city is working to optimize administrative and operational procedures and implement smart traffic systems to improve traffic flow and reduce congestion.

Smart Living: Focused on promoting sustainable cooling and energy efficiency in residential and commercial buildings. The city is working to implement district cooling systems, which use waste heat from industry, cogeneration plants, or waste incineration to generate district cooling.

3.2.13 Dublin

Dublin is included in four latest editions of selected indexes except from *GCI 2023* and has an average rank of 33.75. The Smart Dublin initiative was launched in 2016 by four local authorities, with the aim of bringing together multiple stakeholders including smart technology providers, academia, and citizens to collaborate and solve city challenges. To accelerate these partnerships, the Dublin city council carefully selected three areas across the city to turn them into smart districts that could pilot and testbed innovative solutions before they are scaled nation-wide. The Smart Docklands district, established in collaboration with Trinity College's research centre, is a testbed for technological and other innovative solutions, with over 250 participants actively coming up with ideas to solve waste management, flooding, and congestion issue.

According to *GPCI 2023*, Dublin ranked #6 in economy. In *CIMI 2022*, the city ranked #6 in economy as well, performed fairly in #29 international profile, poorly in other dimensions such human capital #93, social cohesion #49, environment #42, governance #70, urban planning #56, technology #121, and mobility and transportation #65.

Smart Economy: Focuses on developing a strong and innovative economy by leveraging smart technologies and data-driven solutions. The city aims to attract high-tech companies, foster entrepreneurship, and create a vibrant business environment.

Smart People: Improve the quality of life for residents by promoting equal opportunities, education, and social inclusion. Involves citizens in the development of Smart City projects, fostering collaboration and engagement ensuring that residents are at the centre of decision-making processes.

Smart Governance: Focuses on promoting transparency, collaboration, and citizen engagement in city governance. Engages with smart technology providers, researchers, and citizens to address challenges and improve city life through innovative governance practices.

Smart Environment: Promote sustainability, reduce carbon emissions, and enhance environmental quality. Implementing projects to address waste management, flooding, and congestion issues, with a focus on sustainable solutions.

Smart Mobility: Piloting projects in sustainable mobility, electric bikes, and smart parking to enhance transportation options for residents to improve traffic flow, reduce emissions, and enhance mobility services.

Smart Living: Creating a more livable, inclusive, and connected urban environment for residents. Promote social cohesion, digital connectivity, and community engagement. Engages citizens, researchers, and technology providers to develop smart living solutions that enhance urban life and create a more prosperous and resilient city.

3.2.14 Helsinki

Helsinki is included in four latest editions of selected indexes except from *GCI 2023* and has an average rank of 16. The city's Smart City initiatives are driven by a vibrant innovation ecosystem and active citizen involvement. Helsinki aims to become the “most functional city” by emphasizing design thinking in solving urban challenges. Recognized as the "*European Capital of Smart Tourism*" Helsinki excels in smart mobility, enhancing tourists' engagement with the city. Initiatives like the *Jätkäsaari Mobility Lab* have revolutionized maritime tourism with services like *Bout, an “Uber for boats”* concept, and the Norsö Line for water transportation.

According to *GPCI 2023*, the city ranked #4 in environment. In *CIMI 2022*, it ranked #7 in environment and #10 in social cohesion, performed fairly in #21 governance and #20 urban planning, poorly in economy #41, human capital #63, international profile #46, technology #49, and mobility and transportation #42.

Smart Economy: Leverages its highly educated population and strong research institutions to drive knowledge creation and innovation.

Smart People: Empower citizens and their quality of life through technology. Promotes digital inclusion by providing open access to data, enabling citizens to shape their urban environment.

Smart Governance: Focusing on effective decision-making and collaboration. Leverages technologies and data to enhance governance processes, ensuring transparency and efficiency. Policy and legal frameworks are established to address challenges associated with Smart Cities, promoting citizen engagement, social inclusion, and economic growth.

Smart Environment: Emphasizes sustainability and environmental stewardship. Committed to achieving carbon neutrality by 2030. Integrates environmental considerations into city planning and transforming waste into sustainable materials.

Smart Mobility: Improve traffic flow, reduce emissions, and enhance transportation systems. Prioritize safety, sustainability, and efficiency, enabling residents to navigate the city seamlessly while reducing environmental impact.

Smart Living: Creating a technologically advanced, entrepreneurial, innovative, sustainable, and socially inclusive city. Enhancing the quality of life for residents by adopting smart solutions that promote well-being and sustainability. Providing open access to data, encouraging innovation, and fostering a culture of entrepreneurship.

4 RESULTS AND DISCUSSION

This chapter deals with the summary of findings, recommendations, and discussion towards improving the current state of development of selected Smart Cities based on the findings identifying in previous chapters.

This thesis focuses on selected cities, including London, New York, Paris, Tokyo, Berlin, Washington, Singapore, Amsterdam, Copenhagen, Seoul, Zurich, Vienna, Dublin, and Helsinki. The analysis of the selected cities reveals that London ranks highest in terms of overall Smart City development, showcasing a comprehensive approach to integrating technology, sustainability, and innovation into its urban fabric.

New York and Paris are two prominent Smart Cities that closely follow London in the rankings, demonstrating strong commitments to innovation, sustainability, and economic growth. New York's Smart City development is driven by its focus on leveraging technology and data for economic development and sustainable practices. The city's New York City Internet of Things Strategy is a prime example of this approach, aiming to develop a Rapid IoT program to allow agencies to deploy short-term, low-cost IoT solutions to gather data and improve city services. The city's commitment to sustainability is evident in initiatives like LinkNYC kiosks, which provide free Wi-Fi with data collection for better resource management, and the NYC Energy Conservation Code, which promotes energy-efficient buildings.

Paris, on the other hand, has embarked on ambitious projects like the Paris Smart City 2050 initiative, emphasizing sustainability and urban transformation through innovative energy solutions and urban planning. The city's strategic plan "Paris Smart and Sustainable Looking ahead to 2020 and beyond" highlights the importance of digital technology in driving economic growth and sustainability. Paris aims to reduce greenhouse gas emissions by 2050, in line with the Paris Climate-Air-Energy Action Plan Towards a Carbon Neutral City And 100% Renewable Energies. The development of energy-plus towers is one of the initiatives aimed at combating the urban heat-island effect, increasing urban density, and integrating nature into the cityscape.

Tokyo, Berlin, and Washington lag in the rankings, facing challenges in certain dimensions of Smart City development.

Tokyo, with a population of over 30 million, Tokyo has been actively engaged in Society 5.0 initiatives, prioritizing the installation of Smart Cities to address social and economic challenges related to mobility, health, tourism, energy, environment, and finance. Despite its forward-thinking approach and engagement in Society 5.0 initiatives, struggles in areas like social cohesion, environment, and urban planning. To address these challenges, Tokyo could focus on implementing policies and initiatives that promote social inclusion, environmental sustainability, and urban planning best practices.

Berlin and Washington also face challenges in specific dimensions of Smart City development. Berlin has an average rank of 17.4 and has been actively working on implementing Smart City strategies to improve the quality of life for its residents and enhance its competitiveness. However, the city performs poorly in technology, social cohesion, and economy, highlighting the need for targeted initiatives to address these challenges. Washington, on the other hand, has an average rank of 25 and has launched various programs to bridge the digital divide and attract high-tech companies. However, the city faces challenges in social cohesion and environment, which are critical for a holistic Smart City strategy.

To improve Smart City development in these cities (Berlin and Washington), policymakers and stakeholders could consider several strategies. They could prioritize social cohesion and inclusion by implementing policies and initiatives that promote social equity, diversity, and inclusion. This could include initiatives that address housing affordability, transportation equity, and access to digital services. Focus on environmental sustainability by implementing policies and initiatives that promote renewable energy, energy efficiency, and waste reduction. This could include initiatives that promote the use of electric vehicles, the development of green spaces, and the implementation of sustainable transportation systems.

Prioritize urban planning best practices by implementing policies and initiatives that promote sustainable urban development, smart mobility, and livable urban spaces. This could include initiatives that promote walkability, bikeability, and public transportation, as well as initiatives that promote the development of green spaces and the preservation of cultural heritage.

Cities like Singapore, Amsterdam, and Copenhagen have shown promising development in various dimensions of Smart City initiatives, setting examples for sustainable urban transformation. These cities have leveraged technology and innovation to address urban challenges effectively. However, there are still areas where improvements can be made to further enhance their Smart City initiatives.

Singapore, known for its Smart Nation Singapore strategy, has been a pioneer in leveraging technology for urban transformation. The city-state's focus on initiatives like the Personal Alert Button demonstrates its commitment to enhancing citizen safety and well-being through innovative solutions. To further advance, Singapore could continue to invest in digital infrastructure and data-driven decision-making to optimize urban services and improve overall quality of life. Enhancing digital literacy among citizens and fostering a culture of innovation and entrepreneurship could also contribute to Singapore's Smart City journey.

Amsterdam's emphasis on sustainability, circular economy, and smart mobility has positioned it as a leader in environmental initiatives. The city's commitment to reducing carbon emissions and promoting eco-friendly practices is commendable. To build on this success, Amsterdam could further integrate circular economy principles into its urban planning, encourage sustainable transportation options, and expand initiatives that promote energy efficiency and waste reduction. Collaborating with startups and entrepreneurs to develop innovative solutions for urban challenges could also drive further progress in Amsterdam's Smart City agenda.

Copenhagen's achievements in reducing carbon emissions while fostering economic growth through smart energy projects highlight its dedication to sustainable urban development. The city's EnergyLab Nordhavn project is a prime example of its innovative approach to smart energy systems. To enhance its Smart City initiatives, Copenhagen could focus on scaling up sustainable energy solutions, expanding smart mobility infrastructure, and promoting digital innovation in urban planning and governance. Engaging citizens in co-creating Smart City solutions and ensuring inclusivity in decision-making processes could further strengthen Copenhagen's position as a sustainable and innovative Smart City.

Seoul, Zurich, Vienna, Dublin, and Helsinki are among the cities that have made significant strides in specific dimensions of Smart City development, emphasizing the importance of tailored strategies to address unique urban challenges and opportunities.

Seoul has implemented various Smart City initiatives, such as the Sharing City Seoul project, which aims to promote sharing economy practices in various sectors, including transportation, housing, and public services. The city also has a comprehensive smart mobility strategy, with a focus on electric vehicles, public bike-sharing systems, and intelligent transportation systems. However, Seoul could improve its social cohesion and environmental initiatives, as it still faces challenges in these areas.

Zurich has set ambitious targets for reducing energy consumption and greenhouse gas emissions, and it has implemented various smart mobility solutions, such as an extensive public transportation network and a focus on promoting sustainable transportation modes like walking, cycling, and public transportation. Zurich could further enhance its social cohesion, environment, and mobility and transportation strategies.

Vienna has been recognized for its commitment to environmental sustainability and climate change mitigation. The city has set ambitious targets for renewable energy generation, energy efficiency, and climate change mitigation. Vienna could further improve its smart mobility strategies, particularly in the areas of eco-friendly mobility, renewable energy, and efficient use of resources.

Dublin has established smart districts, such as the Smart Docklands district, which serves as a testbed for innovative solutions to waste management, flooding, and congestion issues. Dublin could further enhance its social cohesion and technology strategies which would help improve their Smart City development.

Helsinki has been recognized for its efforts in promoting smart mobility solutions, such as the Helsinki Regional Transport Authority's MaaS Global service, which offers a comprehensive mobility-as-a-service platform that integrates various transportation modes, including public transportation, taxis, car-sharing, and bike-sharing. Helsinki could further improve its human capital and mobility and transportation, particularly in the areas of green spaces.

Some other trends to consider to further enhance the development of Smart Cities could be integration of advanced technologies such as AI, including generative AI, and ML can significantly enhance the efficiency and effectiveness of urban systems. AI and ML can analyse large amounts of data, identify trends and patterns, and optimize resource allocation, leading to improved city operations and management.

Data privacy and security are critical aspects of Smart City development. Implementing robust data protection measures, such as encryption, access controls, and data anonymization, is essential to protect the personal data of citizens and ensure the secure operation of Smart City systems. Urban agriculture is gaining popularity in Smart Cities, focusing on the integration of agriculture and food production systems within urban environments. Initiatives such as urban farms, rooftop gardens, and vertical farming systems contribute to the creation of a more sustainable and self-sufficient urban food system.

CONCLUSIONS

The aim of the bachelor thesis was to analyse indicators used to evaluate development of Smart Cities and compare selected cities in terms of most relevant indicators. The aim of the thesis was successfully fulfilled. Chapter 1 provides the theoretical background for this topic. Chapter 2 then includes identification and description of Smart Cities characteristics and indicators, including tools and frameworks and their structure. The main part of the thesis is represented by Chapter 3 which deals with data analysis and comparison of selected cities. Chapter 4 then provides results and discussion towards the topic.

The findings of this thesis are expected to (1) provide urban planners, policymakers, and stakeholders with a comprehensive understanding of Smart City development, (2) offer a systematic and data-driven approach to evaluating and comparing Smart Cities, (3) contribute to the advancement of evaluation frameworks and methodologies in the realm of urban development, (4) inform future Smart City initiatives and investment decisions, and (5) advance the theoretical discourse surrounding Smart Cities and urban development.

This thesis highlighted the importance of digital technologies in addressing urban challenges, such as resource consumption and environmental concerns. The emergence of the IoT and AI has played a crucial role in the development of Smart Cities, providing the infrastructure for interconnected ecosystems within cities. The analysis has also revealed that cities like London, New York, and Paris are leading the way in Smart City development, demonstrating strong commitments to innovation, sustainability, and economic growth. However, cities like Tokyo, Berlin, and Washington lag behind in certain dimensions, highlighting the complexities of implementing holistic Smart City strategies in diverse urban contexts.

Future research could also focus on analysing successful Smart City projects and identifying the factors that contribute to their success and conduct a comparative analysis of Smart Cities across different indexes and rankings, e.g., the economy ranking between New York and London for different indexes which can provide valuable insights into the strengths and weaknesses of various urban development strategies.

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