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An economical, sustainable and technological analysis of impact of the smart cities

The case study of Barcelona and Singapore

Loris Guernieri

Master Thesis

presented as partial requirement for obtaining the Master Degree in Information Management

NOVA Information Management School
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An economical, sustainable and technological analysis of impact of the smart cities

The case of Barcelona, Singapore.

by

Loris Guernieri

Dissertation presented as partial requirement for obtaining the Master's degree in Information Management with a specialization in information system and technology management

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DEDICATION

I am proud to have achieved this and to have reached the end of my Master's degree, I would like to thank Professor Vitor Santos for his availability and the help he gave me during my thesis writing process, my family for supporting me through difficult times and every day during my university career, furthermore, as a student coming from another country, I thank Teleperformance for giving me the opportunity to work part-time and support me in my first year, I thank all my friends and classmates I met in this fantastic city, especially Lorenzo with whom I decided to undertake this experience and Lloyd also a milestone in my university career. Without each and every one of them I would not have achieved this result, I would also like to thank my cousins in particular Simone and Natalia, my grandmother Elsa and my grandparents who I missed before I embarked on this experience, I hope you are proud of me.

ABSTRACT

This study performs a comparative analysis of smart cities in Barcelona and Singapore with the aim of exploring the interactions between economic development, technology, and sustainability, as well as identifying the international climate change guidelines, regulatory patterns, and performance of these case studies. Employing a descriptive qualitative methodology supported by visual data, the study scrutinizes data from voluntary reports, municipal datasets, international reports, and academic literature. The results indicate that both cities are actively implementing technological solutions to reduce energy consumption and enhance the efficiency of public services. However, despite adhering to various international climate change guidelines and exhibiting distinct regulatory patterns, more concerted effort is needed to achieve the sustainability goals outlined in the 2030 Agenda. This is particularly true in the domains of innovation and citizen engagement. This study contributes to the understanding of how smart cities can balance economic growth and sustainability through the adoption of emerging technologies, while also providing insights into their alignment with global climate guidelines and performance metrics.

Keywords:

Smartcities; Barcelona; Singapore; Sustainability; SDG; Smart Sustainability; Smart Living; Smart Environment; Smart Economy; Smart Technology; Smart Governance.

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GLOSSARY ACRONYMS

ASEAN Association of Southeast Asian Nations: is a regional intergovernmental organization comprising ten countries of the Southeast Asia, which promotes intergovernmental cooperation and facilities economic, political, security, military, educational and sociocultural integration among its members and other countries in Asia. Singapore is part of ASEAN.

C40 Cities Climate Leadership Group: is a global network of cities committed to addressing climate change and promoting sustainable urban development. The C40 was established in 2005 and currently consists of 97 member cities around the world (Moran et al., 2018), plays a crucial role in facilitating collaboration and knowledge sharing among cities to address climate change. Through its initiatives and programs, the C40 supports cities in implementing sustainable and resilient solutions, advocates for cities' interests in global climate discussions, and provides a platform for cities to measure and report their emissions.

CFD Computational Fluid Dynamics simulation is an advanced technology that uses mathematical models and computational algorithms to study and simulate the flow of air, air pollutants and other environmental variables within urban settings.

EU European Union: This is a political and economic union of 27 member states located primarily in Europe, Barcelona is part of the EU.

GDP Gross Domestic Product is a key measure of a country's economic activity. It represents the total value of all goods and services produced within a nation's borders during a given period, usually a year. GDP includes consumption, investment, government spending and net exports and serves as an indicator of the size and economic health of a country.

GHG Greenhouse gases: These gases in Earth's atmosphere trap heat. They allow sunlight to pass through the atmosphere, but prevent heat carried by sunlight from leaving the atmosphere. The main greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide and ozone. Greenhouse gas emissions are a major concern for urban sustainability.

GIS Geographical Information Systems are computer tools that enable the capture, management, analysis and visualization of geospatial data relating to cities.

ICT Information and Communication Technology: It is an umbrella term encompassing any communication device or application, including radio, television, cell phones, computer hardware and software and networks, satellite systems, etc. ICT is a key component in the development and operation of smart cities.

IoT Internet of Things: Refers to the network of physical objects embedded with sensors, software and other technologies to connect and exchange data with other devices and

systems through the Internet. In smart cities, IoT is critical for data collection and management.

MTB Mechanical-Biological Treatment is a waste processing system that combines mechanical sorting and biological treatment. The mechanical component involves separating waste into recyclable materials, combustibles, and residuals, while the biological part includes aerobic or anaerobic processes to stabilize the organic fraction of the waste.

OECD The Organization for Economic Cooperation and Development (OECD) is an international organization composed of 38 member countries, mainly industrialized nations. The mission of the OECD is to promote economic cooperation among member countries to improve economic growth, employment, social welfare and global financial stability. The OECD plays a key role in research, public policy analysis and promotion of best practices in areas such as economics, environment, education and development.

PCT Patent Cooperation Treaty (PCT) patent applications are international applications for the protection of inventions. These applications allow inventors to file a single application in many countries, simplifying the process of obtaining patent rights in several jurisdictions.

RS Remote Sensing is a technology for acquiring geospatial data from remote sensors, such as satellites or drones.

TEA Total Entrepreneurial Activity measures the level of entrepreneurial activity in a particular geographical region or population. It indicates the proportion of adults engaged in entrepreneurial enterprises, both in the form of starting new businesses and running established ones.

WHO The World Health Organization is the specialized agency of the United Nations that focuses on promoting global health, preventing disease, and improving access to quality health care. WHO plays a key role in coordinating the global response to epidemics, providing health guidelines, and promoting equitable and sustainable health policies worldwide. Its mission is to help ensure that all people have the best possible health status.

1 Introduction

Throughout history, human experience has developed knowledge and aspirations for once-utopian goals, thanks to technological advancements. Nevertheless, one constant element in the succession of eras has been the rise and evolution of cities. These centres of civilisation, which arose from necessity and the desire to focus activities around strategic locations such as rivers and industries, have not only been hubs for ideologies, movements, and technologies, but also examples of infrastructural innovation and reference points for entire countries. However, the rising population density in these cities has altered the natural landscape, moulding it to suit human requirements.The smart city concept originated in the United States to describe an idealized highly automated city in which information and communication technologies (ICTs) serve as the supporting infrastructure for smart cities.

In recent times, there has been significant interest in the idea of smart cities, although its origins can be traced back to the past. Since the beginning of the 21st century, cities have endeavored to incorporate Information and Communication Technologies (ICTs) to enhance the standard of living for their inhabitants and address the obstacles faced by urban areas. The association between technology and cities, built up over centuries, has had an impact on the contemporary notion of the smart city.

The concept of smart cities draws inspiration from several urban models where technology plays a central role. Technopolises, for instance, propose ICT advancement in cities as a model. However, the intangible nature and technical complexity of ICT integration present a challenge for urban studies (Hollands, 2008).

The European Union (EU) and the Association of Southeast Asian Nations (ASEAN) share a vision for smart cities that promote sustainable development, resource efficiency, and enhanced quality of life. Through the US-ASEAN Smart Cities Partnership initiative, both regions concur that the innovative use of digital and telecommunications technologies is fundamental to establishing smart cities that optimize traditional networks and services. This would ensure the well-being of citizens and the prosperity of businesses.

According to the EU, a smart city involves the merging of digital and telecommunications technologies to enhance the efficiency of urban infrastructure. This involves not only the optimization of resources and reduction of emissions, but also the improvement of urban transport, advanced water and waste management, and more intelligent lighting and heating systems in buildings. The smart city is an environment in which citizen-administration interaction is improved, public spaces are made safer, and the needs of a changing population are met.

In parallel, the US-ASEAN Smart Cities Partnership outlines smart cities as 'smart and sustainable cities'. These cities were created to achieve economic and social development, with the objective of preserving the environment through proficient governance systems and suitable financial mechanisms. Similarly, the concept stresses the importance of maintaining, reviving, and augmenting urban ecosystems fairly, as the natural resources of cities are fundamental for economic productivity, adaptability to climate change, and standard of living.

The EU's and US-ASEAN Partnership's visions share major similarities and complement each other. Both viewpoints acknowledge the significance of technology, but not as the sole means for developing intelligent cities. The EU prioritizes citizen-administration interaction and the enhancement of conventional services using digital solutions. On the other hand, the US-ASEAN Partnership prioritizes effective governance, fairness and environmental preservation as essential foundations of smart cities (Europen commission website; U.S.-ASEAN Smart Cities Partnership, 2023).

A smart city aims to achieve economic sustainability and energy self-sufficiency, while also developing novel urban mobility models and prioritizing the well-being and requirements of its citizens. The transformation from a city to a smart city is a multifaceted process, requiring significant innovation to

both tangible and intangible infrastructures, living standards, urban redevelopment and design, and economic production.

Dialogue, the mastery of complexity, and, above all, policies and behaviors are required to create livable and competitive communities in a globalized world. This is linked to the changing pace of life and work in "global" cities, ranging from multinational corporations to social enterprises, and from SMEs to universities, research centers, and associations. A range of actors operates within this context, and public institutions, especially local ones, can play a central role in facilitating connectivity and coordination.

Smart cities use ICT to improve the economy, sustainability, and citizens' quality of life. They have embraced technology, which is showing no signs of slowing down. This development can create a more efficient and competitive economy that promotes innovation and entrepreneurship. Additionally, they concentrate on environmental sustainability, aiming to reduce greenhouse gas emissions while promoting renewable energy (Lofhagen & Lira, 2022).

Currently in the midst of a climate crisis, emerging from a pandemic, and experiencing a constant population increase coupled with a decrease in available resources, the importance of efficiently managing the resources provided by nature has become more vital than ever before. As cities are the centres of most of the technologically and economically developed population, it is concerning that several studies have highlighted air pollution in urban centres (Pereira et al. 2022; Madani & Carpenter 2023; Schindler et al. 2017).

As we explore the impact on the population and work towards sustainability and efficiency, it is crucial to focus on cities. They provide the opportunity to develop state-of-the-art infrastructure that can support itself both economically and ecologically. This entails using cutting-edge technology to collect and analyse environmental data (via sensors, video surveillance, waste detection and citizen reports etc. etc.) to establish the most efficient system.

The case studies of Barcelona and Singapore hold significant value in the research of smart cities. These cities have taken the lead in implementing smart initiatives and have achieved remarkable success in integrating technology, sustainability, and economic development. In both cases, technological innovation has been used to enhance services and ensure efficiency.

Thanks to its sophisticated infrastructure, Barcelona was awarded the European Capital of Innovation Award in 2014 (iCapital 2014, n.d.), thus consolidating its position as a cutting-edge smart city that takes a holistic approach to urban transformation. The metropolis has introduced various intelligent solutions to diverse areas such as transportation, energy, and governance. The primary objective of Barcelona's strategy for smart city development has been to enhance the quality of life for its residents by utilizing technology and data analytics in a strategic manner. Using IoT technologies, the city has streamlined energy consumption, improved mobility, and encouraged residents to participate actively (Neirotti et al., 2014).

Barcelona's case study offers valuable insights into the hurdles and prospects involved in executing smart city initiatives. The strategies applied have particularly benefited residential construction, by enabling precise tracking of water and energy consumption, thereby identifying wastage and leakage. Additionally, the transportation, health, and education sectors have also encountered improvements, as well as the streamlining of transactions (Grimaldi & Fernandez, 2017).

Regarded as one of the world's most technologically advanced cities and a driving force behind the Smart Nation initiative, Singapore ranks highly in IQ and school test results (Madden, 2019). The city-state has firmly established itself as a global leader in the development of smart cities by implementing a diverse range of intelligent solutions to enhance the quality of life for its citizens and tackle urban issues. Singapore's smart city strategy centres on enhancing transportation, energy, and urban planning, using data analytics and technology to bolster energy efficiency, sustainable living, and optimize transportation (Bibri & Krogstie, 2017). The Singapore case study provides valuable insights into successful implementation of smart city initiatives within a small and densely populated urban

setting. By deploying technological infrastructure to optimize services and enhancing the 5G network, Singapore has substantially improved its citizens' quality of life. The aspiration to transform the whole nation into a smart society underscores the unwavering commitment to sustainability in driving innovation, even in areas that have traditionally been slow to catch up (Huseien, 2022). To sum up, Singapore's experience offers a valuable model for how a dense urban community can effectively implement smart city tactics to achieve collective benefits.

1.1 OBJECTIVES

This research aims to comparatively study the development of smart cities, with a particular focus on economic, sustainable, and technological aspects. It seeks to explore how two cities, Singapore and Barcelona, address similar challenges despite existing in vastly different geographical, economic, and cultural contexts with distinct histories.

The objective of this study is to analyze the development and adaptation of two cities, exploring potential learning opportunities between them, and serving as a model for other urban areas in the future. Abbreviations for technical terms will be explained upon first use. The analysis draws on international reports, data provided by the cities, and a systematic literature review. A detailed examination of smart cities' dynamics will be conducted, comparing essential factors based on specific criteria.

The objectives are defined as:

O1: Identify the sustainable, economic and technological performance of the case studies.

O2: Identify the sustainable strategies used by the study cities.

O3: To identify the international climate change guidelines, regulatory patterns and performance of the case studies.

The research questions of this study are as follows:

Q1: How are the case studies performing in the following aspects: sustainability economy and technology?

Q2: What are the smart strategies used by the case studies to achieve sustainability?

Q3: What are global organizations doing to address the climate crisis, how are the case studies performing?

1.2 STUDY IMPORTANCE AND RELEVANCE

The swift urbanization process together with the effects of industrialization and globalization emphasize the need for smart city development. With 75 percent of natural resource consumption

and equal pollution and waste creation, innovative technologies and solutions are fundamental for such cities (Shamsuzzoha et al., 2021).

Smart cities aim to utilize human resources by enabling citizens to produce high-tech products and consume innovative solutions (Avdeeva et al., 2019). Nonetheless, climate change represents the most significant issue in modern cities, with human activities accelerating the trend, resulting in increasing temperatures, droughts, floods, rising sea levels, loss of biodiversity, and weather imbalances (National Geographic, 2016; Global Warming, n.d.).

An examination of case studies on Singapore and Barcelona, regarded as a smart city leader and up-and-coming city respectively, reveals noteworthy practices and lessons learned. Adhering to the seminal Giffinger model (Giffinger et al., 2015), this analysis will investigate the social, economic, and environmental aspects of these cities to identify successful strategies. By sharing these practices, other cities globally can avoid errors and adopt established procedures (Avdeeva et al., 2019).

In addition, Barcelona and Singapore's adoption of the United Nations Sustainable Development Goals (SDGs) are clear examples of how smart city strategies can contribute to specific goals (THE 17 GOALS | Sustainable Development, n.d; Barcelona, 2030 Agenda, n.d.; Singapore, Singapore's Sustainable Development Goals, n.d.).

The use of common metrics, as advocated by the World Council on City Data (WCCD) (WCCD, n.d.), plays a crucial role in promoting urban sustainability. The examination of cities as separate entities within a nation, as recommended by Patricia McCarney, provides a tactical method to enhance urban productivity and enable national evaluation (McCarney, 2021).

It is essential to consider the distinctiveness of each city and country, adjusting smart city policies and strategies accordingly to their requirements, objectives, and resources (Razmjoo et al., 2022). What works in one city may not be effective in another; hence, policy decisions must rely on individual and contextual evaluations.

The study analyzes the climate threat and the actions taken by humanity to address it. Specifically, it examines the economic, technological and sustainable strategies employed by Singapore and Barcelona to facilitate technological growth and progression. The chosen study is focused on cities to ensure greater precision. Ultimately, this research aims to offer valuable insights for policy and decision makers, with the potential to facilitate more sustainable and efficient cities globally.

2.Literature Review

This research adopts a literature review methodology to examine scientific research articles and generate a methodical overview with detailed insights. To achieve this aim, only the latest scientific publications were utilized. Additionally, in exploring the case study methodology, I will examine cities and consult the database and voluntary reports provided by the country/city under investigation. I will also analyze international reports and conferences, including OECD, WHO, and the United Nations.

If required to explain fundamental information, I may refer to earlier literature. We considered publications in journals with a high impact factor, as evaluated by Scimago Journal & Country Rank. Articles were deemed relevant based on their relation to the case studies and adherence to the criteria.

I have chosen to apply the search criteria typically used in university courses, which include: relevance, to identify studies related to the topic; validity, to evaluate methodological quality and result validity; accuracy, to verify the correct representation and precision of the data; and completeness, to ensure all studies on the topic are identified; reliability one assesses the competence and reliability of authors and sources and Objectivity (Booth et al., 2012).

In addition, relevant experts in the field were cited to enhance the purpose of the thesis. Articles from journals such as the New York Times and Forbes were utilized for this purpose. With the goal of enhancing comprehensibility, this analysis examines each article to clarify the author's perspective. It aims to depict the situation of the case study cities as objectively and accurately as possible, and to provide additional insights where necessary. Technical terms are explained when first used to ensure a clear and logical flow of information. The text adheres to conventional academic structure and style, maintaining a formal register and precise word choice. Biased language is avoided and the grammar is grammatically correct.

This will be a literature review of the topics under examination, demonstrating how previous articles have outlined the parameters in their studies.

2.1 RELEVANT CLIMATE CRISIS CONFERENCES

Global warming, as evidenced by scientific research, has caused substantial changes in the epigenetics, physiology, and phenotypes of numerous organisms spanning from microbes, plants, and coral reefs to insects, fish, birds, and mammals (Skinner, 2022).

One simply must examine the temperature fluctuations chart of the past 142 years to observe the discrepancy:

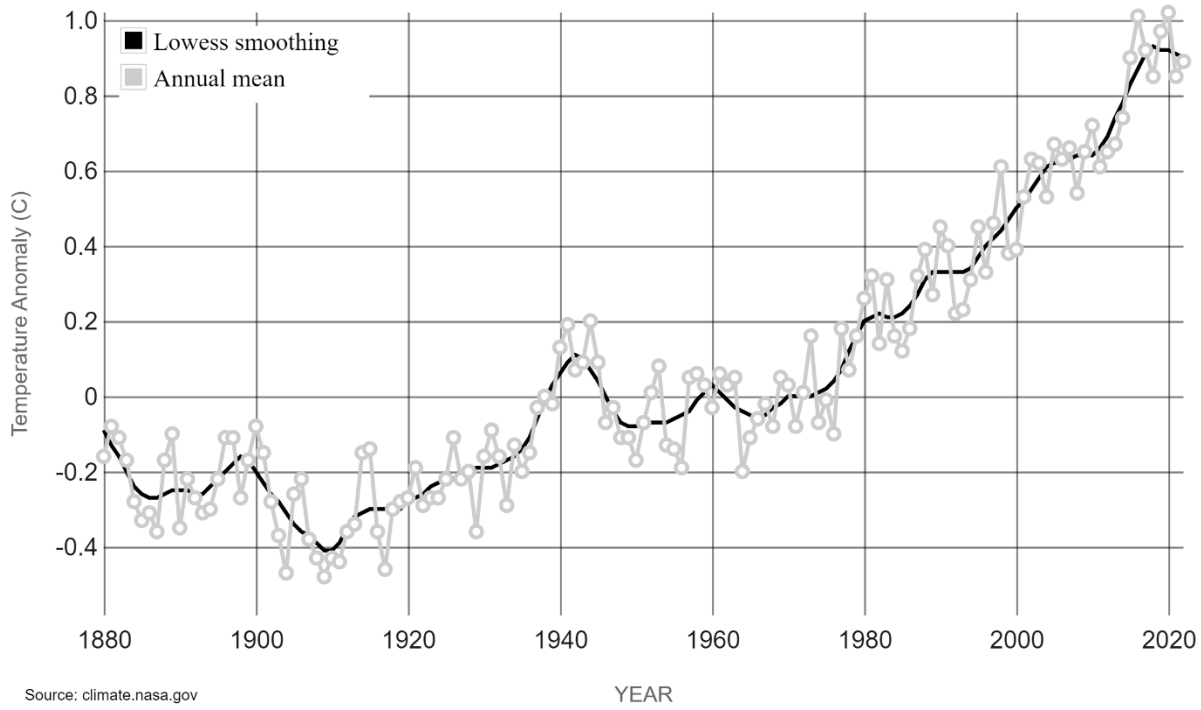

Figure 2.1 Global land-ocean temperature index (1880-2022) Source:(Data.GISS: GISS Surface Temperature Analysis (V4): Analysis Graphs and Plots, 2023).

The chart illustrates the variation in worldwide surface temperature from the long-term average between 1951 and 1980. According to NASA/GISS, the year 2020 is statistically comparable to 2016 as the hottest year since records began in 1880.

Rising temperatures and shifts in climate patterns related to global warming may upset ecosystems and biodiversity thereby causing the disappearance of species and habitats (Hof et al., 2018). Furthermore, global warming adds to the environmental load including increased air pollution and the emission of greenhouse gases, which intensifies the climate predicament (Holka & Bieńkowski, 2020). 97% of climate scientists agree that human activity is causing global warming. The planet is warming at a rate of four atomic bombs per second, with climate models confirming the man-made cause of global warming. Moreover, the negative impacts of climate change are affecting all sectors of society. A National Geographic documentary states that existing technology can be employed to resolve the problem of climate change. (Global Warming of 1.5 oC -, n.d., (Stevens, F. 2016).

Public perception of climate change varies across regions and cultures. Whilst there is evidence that climate change is not always seen as a pressing concern, there is backing for global climate initiatives that do not overly burden individuals. Nevertheless, greater effort is required to enhance comprehension and consciousness of climate change, as an absence of understanding and reluctance to make sacrifices impedes effective mitigation and adaptation measures. Furthermore, the potential impacts of global warming, such as extreme weather events and rising sea levels, may influence individuals' risk perception and willingness to act (Wullenkord & Reese, 2020; Bord et al., 1998).

2.1.1 Historical Climate Action

Since 1992 (Groundbreaking Rio Earth Summit), when the United Nations acknowledged climate change as a pressing issue, negotiations between nations have led to significant agreements such as the Kyoto Protocol and the Paris Agreement. However, world leaders appear incapable of complying with these agreements, resulting in a failure to decelerate the increase in global temperatures (Maizland, 2019).

The **Kyoto Protocol** is an international agreement, adopted in 1997, that prescribes binding targets for reducing greenhouse gas emissions by developed nations. The protocol provides flexible mechanisms, including emissions trading and the Clean Development Mechanism.

The primary aim of the agreement was to decrease the release of six greenhouse gases (CO2, CH4, N2O, HFCs, PFCs, SF6). The protocol established particular reduction targets for carbon emissions in developed countries during the commitment period of 2008 to 2012.

A crucial aspect of the Protocol is the array of flexible measures it provides nations to fulfil their emissions reduction objectives, such as emissions trading and the Clean Development Mechanism (CDM). The latter permits developed nations to invest in mitigation projects in developing countries.

The agreement was a significant milestone as it constituted the inaugural obligatory pact to address climate change, despite notable restrictions. The most substantial limitation is its coverage of merely a fraction of countries due to the lack of ratification from significant emitters like the US. Moreover, the reduction targets outlined in the protocol are inadequate to attain the ultimate objective of stabilising greenhouse gas concentrations in the atmosphere (UNFCCC, 1998).

The **Paris Agreement** is a binding agreement. It is an international climate change treaty that was adopted in 2015 by 196 Parties during the United Nations Climate Change Conference (COP21). Its main objective is to limit the increase in global average temperature to no more than 2°C above pre-industrial levels, with a follow-up effort to limit the increase to 1.5°C above pre-industrial levels.

In recent years, there has been a significant focus from global leaders on limiting global warming to 1.5°C by the end of the century. This is based on the scientific findings of the UN Intergovernmental Panel on Climate Change that indicate exceeding the 1.5°C threshold increases the risk of severe climate change impacts such as droughts, heatwaves and more frequent and intense precipitation. To limit global warming, greenhouse gas emissions must peak by 2025 at the latest and decrease by 43% by 2030.

The Agreement is a significant achievement in the multilateral process of addressing climate change as it is the first legally binding agreement to bring together all nations in the effort to combat climate change and adapt to its impacts.

Implementing the Accord necessitates an economic and societal transformation founded on the preeminent available science. It operates on a five-year cycle of climate action expansion by countries, with National Climate Action Plans (NDCs) submitted since 2020. Every subsequent NDC ought to exhibit greater ambition in comparison to the preceding one.

Recognizing the need for accelerated action to limit global warming to 1.5°C, the decision of COP27 states that the 2030 targets in their NDCs should be reviewed and strengthened to align with the temperature target of the Paris Agreement by the end of 2023. This should be done while considering different national circumstances (UNCCC, 2023).

COP26 proved to be a noteworthy gathering that united 120 global magnates along with more than 40,000 registered participants, consisting of 22,274 delegates from parties, 14,124 observers, and 3,886 members of the media. Over a two-week period, all aspects of climate change captured global

attention, including the science, potential resolutions, political determination to act, and explicit directions for action.

Though subjective evaluations are excluded, they serve as a reference point and practical approach towards limiting temperature increase to 1.5 degrees by the year 2030 compared to current values by reducing emissions. The United States, under the Trump presidency, withdrew from the Paris Agreement, before rejoining once again during the Biden presidency, Russia, while joining, has made no statement on active participation; these two countries are respectively the second and fifth largest emitters in the world. (Global carbon project 2021). Cop26 attempted to increase awareness of the issue and provide more guidance to nations in order to achieve more effective outcomes and support developing countries in sustainable development (Lennan, M. & Morgera, E. 2022).

2.1.2 Agenda 2030 (SDG)

In 2015, the United Nations initiated the 2030 Agenda for Sustainable Development, which comprises 17 Sustainable Development Goals (SDGs) agreed upon by all 193 UN member states. The agenda advocates for measures to enhance individuals' livelihoods and safeguard the surroundings (Crespo et al., 2017). Nonetheless, the COVID-19 pandemic has jeopardized the progress towards these goals, necessitating a global revitalization strategy. Instead of subjectively evaluating the crisis as a mere misfortune, it presents an opportunity to direct innovation towards a sustainable future, given its profound impact on people's lives (Martiroli, 2020; Martin, 2020). The 2030 Agenda, or Sustainable Development Goals (SDGs), is a framework introduced in 2015 by the United Nations to tackle social, economic, and environmental challenges by 2030.

A fundamental principle of the agenda is to avoid leaving anyone behind by attending to the needs of the most vulnerable populations.

The implementation of the agenda necessitates global, national, and local level action directed towards interconnections between goals and data collection for monitoring purposes. Partnerships between governments, civil society and the private sector are required (Transforming Our World: The 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs, n.d.).

Figure 2.2: List of SDG, Source: (Martin, 2023)

Below is a revised and factually accurate description of each objective, the detail of the SDG and the respectively description can be fount in the official website for the UN here. (Crespo et al., 2017; Kharrazi et al., 2016; Vyas-Doorgapersad, 2022; *THE 17 GOALS | Sustainable Development*, n.d.).

The establishment of the SDGs was motivated by the acknowledgement of the interdependence of worldwide issues and the necessity for an all-inclusive method to achieve sustainable development. The occurrences and engagements that culminated in the description of the SDGs emphasized the significance of charting the correlations between objectives, considering numerous sustainability perspectives, and handling compromises. These insights have influenced the design and execution of the SDGs, highlighting the significance of integrated and collaborative methods to realize sustainable development.

2.1.2.1Collaboration between Cities for Global Sustainability

Smart cities have arisen as a response to the multifaceted challenges confronting urban areas, including sustainability and climate change. Implementing the SDGs has become critical for cities to tackle these challenges. This section investigates the significance of collaboration amongst cities and the use of the SDGs as benchmarks for smart cities, and how cities necessitate indicators to gauge their performance. Existing indicators at the local level are frequently neither standardised nor consistently comparable over time or throughout cities. ISO 37120:2018 (2019) COP26 convened 120 global leaders with the goal of coordinating a collective global response. Therefore, a collaborative and unified approach is necessary to combat the issue. Communication technologies and uniform indicators enable cities to be analysed and compared, which facilitates the adoption of effective solutions employed by others, thereby enhancing their technological and sustainable economic development.

Collaboration among cities is vital in addressing global issues such as sustainability and climate change. The Paris Agreement acknowledges the significance of international cooperation in preventing, minimizing, and tackling the adverse impacts of climate change (Schmalenbach, 2022).

By working together, cities can exchange best practices, share knowledge, and learn from each other's experiences. This cooperation can result in the creation of groundbreaking solutions and the hastening of sustainable development efforts (Leavesley et al., 2022).

The SDGs offer a broad framework for assessing progress towards sustainable development. They provide a shared language and a set of benchmarks that enable cities to assess their progress and pinpoint areas for enhancement. The accord applies to countries that are required to take action to fulfil the minimum required standards, yet some cities have chosen to follow the targets by presenting their progress in comparison to the reference cities. Barcelona and Singapore have both recently updated their websites and voluntarily reported on their performance.

By aligning its smart city strategy with the principles of the SDGs, Barcelona can evaluate its progress in areas such as sustainable urban development, renewable energy and social inclusion. This assessment can aid in identifying areas in which Barcelona excels and those that require more attention (March & Ribera-Fumaz, 2016).

By using the SDGs as an evaluative tool, Singapore can ascertain its performance in areas such as sustainable transportation, waste management, and climate action. This analysis could assist Singapore in improving its strategies and identifying opportunities for collaboration with other cities (Yoo, 2021).

In addition to the SDGs, cities such as Barcelona and Singapore are involved in a range of international climate and sustainability agreements and initiatives. For instance, the C40 Cities Climate Leadership Group unites cities committed to tackling climate change. Barcelona and Singapore are both part of this network, which enables the exchange of knowledge and cooperation among cities (Lopez et al., 2021). Such collaborations enable cities to benefit from shared experiences and work towards shared objectives.

2.2. SMART CITY CONCEPT

By 2050, it is predicted by the United Nations that 66% of the global population will reside in urban areas (United Nations, 2014). Currently, cities are responsible for consuming 75% of the world's energy and generating almost 80% of greenhouse gases that have negative impacts on the environment (Mohanty et al., 2016; Nam and Pardo, 2011a).

The concept of smart cities emerged in the 1970s, when Los Angeles created the first data-rich urban project called 'A Cluster Analysis of Los Angeles'. The initial smart city was Amsterdam, which established a computer-generated municipal area in 1994. Afterwards, advancements quickened in the mid-2000s when IBM and Cisco introduced their individual initiatives. The very first Smart City Expo World Congress occurred in Barcelona in 2011 and has since become a regular event that monitors the growth of smart municipalities (Intelligence, 2022).

Smart cities aim to enhance services and ensure a superior quality of life by continuously monitoring residents and infrastructure, enabling instant communication in case of suboptimal performance (Smart Cities, n.d.). This is accomplished by employing technologies such as IoT, IoD and IoV, which produce evaluated data to enhance efficiency and effectiveness. The deployment of advanced hardware devices including wireless sensors, smart meters, smart vehicles, smartphones, mobile networks, and data storage technologies, backed by specialized software, could facilitate smart traffic management, electricity provision, city monitoring, smart construction, and patient health tracking, among other offerings (Peng et al., 2017; Heidari et al., 2022).

Smart cities encounter difficulties associated with resource scarcity and technological advancements. This ecosystem intends to enhance the standard of living of citizens by promoting personal, social, cultural, economic, environmental, and physiological well-being amongst city residents, while streamlining city administration (Almihat et al., 2022). To ensure a sustainable approach, it is important to consider digital infrastructure, internet access, smart mobility solutions, connectivity, and e-governance initiatives (Ahvenniemi et al., 2017; Ahad et al., 2020; Shamsuzzoha et al., 2021).

Smart city initiatives encompass various dimensions, such as mobility, environment, energy, sustainable construction, technological advancement, and social integration. This comprehensive outlook facilitates the resolution of intricate urban issues, from climate variability and urbanization to societal fragmentation and economic unpredictability. These problems require innovative solutions and long-term strategies that consider the interconnections and mutual implications between the different dimensions.

To adequately address the varying viewpoints of technology specialists, researchers, local governments, private enterprises, and civil society, it is essential to examine the distinctive dimensions relevant to technology tools and the requirements of each party. By including these various perspectives, an all-encompassing model may be developed that embodies a cohesive vision of the smart city and facilitates straightforward communication between all parties involved (Shamsuzzoha et al., 2021b).

The comprehensive participation of all societal sectors is imperative for a genuinely meaningful development of smart cities. Evaluating the resilience of diverse urban areas and mitigating associated vulnerabilities is crucial to guarantee the creation of more sustainable and sturdy smart cities (Fernandez-Anez et al., 2018).

2.2.1 Smart Economy

The concept of the 'Smart Economy' pertains to a municipality's economy, with a focus on reinforcing and transforming it through general enhancements to the business environment, appeal to start-ups, investors, firms, and fresh talent. The goal is to generate economic growth in an innovative and sustainable manner to enhance competitiveness (The 'Smart Economy', n.d., p. 35). It is crucial to acknowledge that the geographic location of economic activities impacts mobility, commuting and productivity. Additionally, the adaptability of the labor market towards new activities, particularly the services sector, is contingent on a skilled workforce (HEC Paris, 2021).

The implementation of clever technologies and forward-thinking methods contributes to financial growth, generating stable and beneficial circumstances for all stakeholders (The Smart Economy, n.d., p. 35). Smart economic development is an essential instrument in government's toolbox, enabling them to capitalize on prospects and establish favorable circumstances for business creation and job creation (Bee Smart City 2022).

The smart economic development dimension of smart cities pertains to utilizing intelligent technologies in supporting sustainable economic growth. Such includes implementing digital infrastructure, fostering innovative business ecosystems, digitizing business activities, and utilizing smart data to promote innovation, productivity and economic competitiveness (Shamsuzzoha et al., 2021).

At the financial level, increased investment is required to enhance ICT infrastructure and services to meet the objectives of smart cities. The participation of multiple sectors, including industry, research institutes, businesses, the government, and citizens, is essential to attract further investment (Noori et al., 2020; Razmjoo et al., 2022).

Smart cities have the potential to attract foreign investments, given their reputation as innovative and technologically advanced places. This results in an increase in economic competitiveness and the establishment of an environment conducive to business (Shamsuzzoha et al., 2021b).

The analysis of entrepreneurship, innovation, and productivity, as well as local and global interconnectedness, is vital to formulating a smart economy. These factors are inherently tied to economic growth, overall development, and community well-being. Such analysis is crucial as it furnishes valuable information for formulating policies and strategies that promote entrepreneurship, foster innovation, enhance productivity and maximize the advantages of connectedness on a local and global level.

The adoption of international and volunteer reports has numerous substantial benefits. These sources offer a worldwide and comparative outlook, enabling cities' performance to be evaluated within a wider context. In addition, these sources offer a reliable theoretical foundation for comprehending the intricacies and difficulties of entrepreneurship and innovation, productivity, and local and global interconnectivity. Moreover, incorporating scholarly reports and articles bolsters the analysis, providing valuable insights and current research into the smart economy.

2.2.1.1 Entrepreneurship and Innovation

Creativity, coupled with digital infrastructure, facilitates entrepreneurship (Zhao et al., 2021).

Smart cities are viewed as urban innovation ecosystems, with significant ICT education and modernization, promoting collaboration between the public and private sectors, enhancing urban efficiency and sustainability (Kummitha 2018). They offer market opportunities to identify and utilize new potential through the creation of new entrepreneurial ventures and by attracting major companies, such as IBM. Cisco, Accenture, and Siemens aim to attract entrepreneurs from less technologically developed cities, allowing them to collaborate and foster economic growth (Kummitha, 2019; Kummitha, 2018b). This collaboration helps to attract skilled human capital and investment, which leads to job creation and increased funding opportunities for businesses and start-ups to access venture capital (Zhao et al., 2021).

For both the public and businesses alike, there will be a lessening of the burden of foreignness, an enhanced ability to utilize Advantage Firm-Specific (FSAs), and increased knowledge transfer (Van Den Buuse & Kolk, 2019).

In situations where development and entrepreneurship are overly or inaccurately pursued, there may be potential for social fragmentation and polarization, as well as a potential for privacy infringement of citizens through data management, risk of technological dependency, and ongoing transitional expenses (Kummitha 2018c; Van Den Buuse & Kolk, 2019b; Zhao et al., 2021).

), the significance of knowledge management (the part played by firms in technology development processes, criticism of the top-down adoption of technology, the flow of knowledge from the bottom-up, collaborations between citizens and companies mediated by public policies, the necessity of information sharing between companies, etc.), the importance of internal organizational partnerships (collaborations between organizations and relevant parties to tackle challenges and foster smart cities, concerns about increased consumption and sustainability, etc.), and ultimately the role of business entrepreneurship (increased collaboration among stakeholders, employment of technology and data to enhance business performance and integrate supply chains, improve customer experience, etc.). Finally, the significance of universities and human capital in data and technology management requires training and skill development (Kummitha, 2019b).

To measure entrepreneurship and innovation, one can refer to reports such as the Global Innovation Index. This report presents a comparative evaluation of countries' innovation potential, including metrics such as scientific publications and international (PCT applications) per capita. In addition, academic articles within the domain of entrepreneurship and innovation may provide a theoretical and analytical viewpoint on the dynamics and difficulties faced in these areas (Herman, 2018).

2.2.1.2 Productivity

The significance of productivity in the smart economy of a city is critical for its economic triumph and competitiveness. As per (Shamsuzzoha et al. 2021), elevated productivity and efficiency, in combination, contribute to a prosperous and desirable economy. Productivity is characterized as the proportion of the volume of output to the volume of input and appraises the efficiency in the use of factors of production. It is a crucial driver of economic growth and competitiveness, offering vital statistical data for international comparisons and country evaluations.

It has a substantial effect on both labor and product market regulations and is a fundamental component in modelling an economy's productive potential. Furthermore, it permits the calculation of capacity utilization and situates the economy within a business cycle. It is also beneficial for predicting economic growth, evaluating demand and inflationary pressures.

The measurement of productivity relies on the measurement's objective and data availability. Indicators such as GDP and the unemployment rate can be used to evaluate productivity (Patel & Tsionas, 2022; OECD. 2021).

In the context of smart cities, ICT plays a crucial role in enhancing labor productivity. EU policies can assist in improving ICT in countries with low productivity (Shahnazi, 2021).

Smart initiatives, including parking apps, access to city services, shared transport services, and smart payments and tickets, can offer users greater convenience and have positive impacts such as cost savings, efficiency, safety, attractiveness, connectivity, sustainability, and smart transport and smart buildings (Wirsbinna and Grega 2021).

Nonetheless, these initiatives may also result in negative effects such as road congestion (Hiscock-Croft 2018).

Overall, measuring and promoting productivity through smart initiatives and the use of ICT is crucial for the economic success and competitiveness of cities and countries in the smart economy. Overall, measuring and promoting productivity through smart initiatives and the use of ICT is crucial for the economic success and competitiveness of cities and countries in the smart economy. This can result in economic benefits and enhancements in the quality of life of citizens.

2.2.1.3 Local and Global interconnectedness

Globalization denotes the growth of economic liberty worldwide, which, in conjunction with the emergence of novel information and communication technologies (ICT platforms, open data, urban laboratories) (Kézai et al. 2020), promotes the progression of democracies, thus stimulating and facilitating enterprise activities. The elimination of constraints on free trade has fostered the development of private establishments and promoted the establishment of business enterprises in the international market. 'Localisation' entails a reorganisation that prioritises the employment of regional resources like labour, land and capital to make commodities and services for local markets, with the aim of building a forward-thinking economy (Lambin, 2014).

Internet connectivity enables daily international and cross-currency transactions. Global interconnectedness denotes the aptness to comprehend and operate within an international, multicultural, and interlinked environment spanning local and global markets. It cultivates individuals who can excel as professionals, civic leaders, and knowledgeable citizens in a diverse national and global community. Physical and online movement of goods (e-commerce, online platforms), services (e-business, research centres), and knowledge (international conferences, collaborative platforms) are essential for enhancing entrepreneurship and innovation ecosystems and providing business support. The objective is to tackle challenges such as shrinking cities, territorial cohesion, mono-sectoral economy, and sustainable local economies (Fernandez-Anez and Velazquez-Romera, 2017; Kézai et al., 2020). The process of globalisation may be limited to a single continent, such as the EU, ASEAN, or NAFTA. Trade and commerce growth is becoming more focused on continental markets. Modern technologies and globalisation work together to facilitate transactions and promote free trade across the globe (Lambin, 2014).

To evaluate the degree of local and global interconnectedness, one can reference sources such as the Global City Index. This report gauges interconnectivity between cities by measuring the exchange of people, goods, information, and capital. Besides that, research papers within the domain of urban studies and networks can yield a theoretical outlook on the interconnectedness dynamics and their implications for social and economic progress (Park & Xie, 2014).

2.2.2 Technology

The significance of technology advancement in smart cities is widely acknowledged as a crucial element in enhancing diverse aspects of urban existence. Technology assumes an indispensable role in streamlining governing mechanisms, advocating sustainable transportation, attaining environmental sustainability objectives and including citizens in the process (Benevolo et al., 2015).

It forms the foundation of smart cities, helping to obtain, examine, and apply data for the enhancement of city services and infrastructure. It encourages the consolidation of diverse systems and devices, which creates a networked environment that enhances efficiency, sustainability, and the well-being of citizens (Capdevila & Zarlenga, 2015). For instance, the use of smart grids encourages proficient energy management, reducing usage and promoting the use of renewable energy sources. Additionally, the use of sensor networks and Internet of Things (IoT) devices enables real-time monitoring of environmental conditions, traffic flow and waste management. This can lead to optimized resource allocation and improved urban planning.

The cases of Barcelona and Singapore demonstrate how technology acted as a catalyst for the success of their smart city programs (Calzada, 2018).

Technology can contribute to several Sustainable Development Goals, including SDG 2, SDG 7, SDG 9 and SDG 11 (Herrero et al., 2021).

2.2.2.1 Technology in daily life

The use of technology is intended to enhance the well-being of residents and visitors through an inclusive strategic approach, covering all age groups and demographics. Promoting livability and improving the management of the living environment are two interdependent aspects that should be considered jointly to maximise the benefits for the local government and its stakeholders.

It centres on enhancing social and digital inclusion (e.g. use of e-services, connectivity, and social platforms), improving healthcare and elderly care (e.g. eHealth, Ambient Assisted Living), safety, housing conditions, and smart buildings (De Castro, 2016).

New techniques for civic and social engagement, along with innovative technologies (e.g. IoT based on Wi-Fi networking technology) are being utilised to enhance accessibility and citizen experience in all areas of concern. (Bee Smart City 2022).

As a complementary factor to external health influences, individuals also consider the quality of education, housing and individual safety. If living conditions deteriorate, people may migrate to other urban communities that they believe offer an improved lifestyle (HEC Paris, 2021).

Safe: It is crucial to secure both public and private spaces through active cooperation between local public organizations, the police, and citizens. This must be done while maintaining respect for fundamental rights, and ensuring security for both individuals and groups. Prevention, sanction, and solidarity policies should be used in combination to achieve this goal. For shared public spaces, security can be enhanced through video surveillance, natural surveillance and citizen participation. Digital security measures like continuity and disaster recovery plans should also be in place. Policing services plans and online policing services can further improve security. (Velazquez-Romera, G. 2017; Statista, 2022).

The Safe Cities Index is a well-established benchmarking tool for measuring safety in urban areas. This index takes into account various factors, including digital security, health security, infrastructure, and personal safety, in order to provide a thorough assessment of urban safety. It has been cited in academic literature and reports as a valuable tool for assessing and comparing the safety of different cities (Kılkış, 2017).

Cultural events: Engaging individuals in cultural and recreational pursuits via ICT, including augmented reality technologies, to enhance information dissemination and accessibility. The aim is to offer novel experiences to audiences in experiencing the cultural legacy of the city. Additionally, the utilization of asset management information systems for the preservation of historical infrastructure. (Velazquez-Romera, G. 2017). Research has indicated that taking part in communal activities, like cultural festivals and religious pilgrimages, can have a favourable effect on a person's well-being (Tewari et al., 2012).

Technological advancements play a pivotal role in making it easier for people to engage with cultural events. They provide the chance for interactive and immersive experiences, giving attendees the opportunity to actively participate and connect with the event content. For instance, the utilization of mobile applications, along with augmented reality and virtual reality, can provide exceptional and custom-made experiences that let individuals explore cultural exhibitions, artworks, and performances in originals ways. At the same time, it can facilitate social interaction and community involvement during cultural events (Meeprom & Fakfare, 2021). Online platforms and social media channels provide individuals with a chance to share their experiences, connect with others, and contribute to the narrative of an event. This digital engagement cultivates a perception of belonging and identity, augmenting the participants' overall satisfaction and enjoyment (Hixson, 2014).

Cultural events are important and covered by SDG 11 which aims to make cities and human settlements inclusive, safe, resilient and sustainable. Cultural events play a significant role in achieving this goal, promoting cultural diversity, community engagement and social cohesion within cities (Blasco et al., 2020).

Healthy: Health technology is pivotal in smart cities as it enhances citizens' quality of life and fosters wellness. Various ICT-based solutions centre on disease prevention, diagnosis and treatment, alongside encouragement of healthy lifestyles and efficient healthcare access. e-Health, telehealth and wearable device monitoring enable continuous monitoring of citizens' vital parameters and health habits, allowing for timely and personalised interventions. In addition, personalized recommendations based on algorithms and personal data offer specific guidance for leading a healthy lifestyle. Recommendation systems can also assist in identifying the most suitable professionals and hospitals for treating specific diseases. These technological solutions not only enhance citizens' health but may also reduce the medium-term costs of the healthcare system (Velazquez-Romera, 2017; Quijano-Sánchez et al., 2020).

By utilizing these technologies, healthcare providers can offer accessible, efficient, and safe healthcare services to residents of smart cities (Tripathi et al., 2020; Szewczenko, 2020).

Incorporating technologies like radio frequency identification (RFID) and electronic health records has enhanced patient identification, management of medication, and general healthcare provision. This approach permits precise and effective monitoring of patients, drugs and medical gear, mitigating the likelihood of mishaps and boosting patient security (Haddara & Staaby, 2018; Ariffin et al., 2018).

The topic falls within the healthcare focus of SDG3.

Smart tourism: The integration of technology into Smart Cities is crucial to enhance citizens' quality of life and encourage the development of sustainable communities (Rodríguez, 2023). The linking of information society and tourism services seeks to create sustainable, responsible and high-standard tourism, providing social benefits and economic growth for local communities.

Technology is disrupting the tourism industry, empowering various applications, online reservation systems, and establishing an interconnected ecosystem of services. An instance of this is the European ICT and Tourism Platform, and how it streamlines the creation of tailored, convenient tourism experiences. Besides, the integration of cards and platforms with other amenities, such as e-mobility, improves the efficiency and convenience for tourists (Velazquez-Romera, 2017).

Smart cities offer modern infrastructure for sustainable tourism development and fair accessibility. The visitor experience is further amplified by complimentary Wi-Fi and the promotion of electric mobility. Real-time information, including traffic flows and public transportation updates, facilitate efficient travel. Additionally, cultural and interactive activities foster a stronger bond between tourists and the local community.

Tourism plays a vital role in the economic growth, job creation, and cultural and social advancement of urban areas (Rodríguez, 2023). Smart hospitality enhances tourists' experience and optimizes hotel operations. Integrating the whole value chain into the smart hospitality ecosystem can offer a competitive advantage.

Smart hospitality benefits both hotels and stakeholders. This includes optimizing competitiveness and enhancing the customer experience. It also benefits macro-level ecosystems, such as regional economic development and tourism attractiveness of destinations, as stated by Buhalis et al. (2022).

The integration of ICT in smart tourism destinations requires dynamic interconnections between stakeholders through sophisticated digital platforms. These platforms allow for real-time information exchange concerning tourism activities to maximize tourist satisfaction and resource efficiency (Aprinawati & Prayogo, 2022). By making better use of ICT infrastructure, destinations can enhance accessibility, inclusivity, and sustainability, aligning with the principles of SDG 11 (Fernández-Díaz et al., 2022).

It can also foster sustainable economic development (SDG 8) by generating employment, bolstering indigenous enterprises, and drawing investment (Casais & Ferreira, 2023).

2.2.2.2 Government Administration

Public management must be at the forefront of technological advancement. This needs to be supported by ample intellectual resources, suitable institutions, and robust infrastructure. It is also imperative to have local spatial development plans in place. These plans will support the connection and interaction between the government and stakeholders, including citizens, businesses, and civil society organizations within a municipality.

To achieve urban development, transparent governance and citizen involvement in decision-making processes are essential.

Smart planning is demand-driven planning. However, we have observed a conflict between policy-driven demands (which are top-down and technology-focused) and stakeholder-driven demands (such as local needs and preferences). From the case study conducted in Sweden by Stratigeo et al. (2015), it was found that local politicians and civil servants held considerable influence. The energy company remained invested in the project, although the university institutions and architects were only involved initially. Surprisingly, the construction companies and future residents showed little interest in the design aspect and only became involved during the construction phase (Axelsson & Granath, 2018). The SDG 16 involves public administration in its development and growth.

A government following a strategic approach is in a special position to reassess the quality, size, and range of services it offers to citizens and businesses. Climate-Friendly Policy Strategies and Perspectives reflect this awareness and responsiveness, stimulating urban developments, inciting urban transformations, and encouraging new initiatives in urban planning.

Through the implementation of new methodologies, including co-creation and crowdsourcing, as well as technological innovations, the potential for improved outcomes can be realized. For digital citizens, business services, and public infrastructure management, the adoption of the "smart government" concept through the assimilation of the "city as a service" model can improve efficiency, effectiveness, transparency, and trust in governance. It is important to evaluate technological developments, especially in terms of citizen participation, data transparency, and the protection of citizens' personal data privacy (Bee Smart City (2022); HEC Paris, 2021 p. 35).

The Abu-Rayash and Dincer (2021) study aims to examine the correlation between governance and the economy. The study findings suggest that a positive linear relationship exists between the smart governance index ratio and the smart economy index ratio. This indicates that smart governance results in a smarter economy, which is more efficient and productive.

Data transparency and open data: As several studies state (e.g., Finch & Tene, 2018), data transparency is important in government as it allows citizens to be up-to-date and informed about the performance of the government and the decisions they make, it benefits citizens' trust, increased credibility, and greater involvement in public decisions, In addition, **open and transparent data** allows businesses, civil society organizations, academics, and developers to use such data to create new solutions, services, and applications that can improve the quality of life for citizens, stimulating innovation and development.

The collaborative ecosystem is a key component of smart cities, supporting solutions that lead to sustainability, economic development and an overall improved quality of urban life. (Clement et al., 2022). Public access to information produced and collected by the government and public entities should be ensured, while considering privacy and security constraints. It is important to ensure that data representation and interpretation are easily accessible.

In addition, transparency tools such as social translucence mechanisms and tracking and analysis should be used. Open Data and Digital Trails: The use of open data, data mining, data visualization, and simulations such as agent-based social simulation can lead to innovative solutions in municipal transparency. Interactive GIS maps of cities and social and citizen service information, i.e., Open Data

of city service performance, can be made visually accessible to all citizens via public sector information (PSI) portals.

Furthermore, a flexible governance approach that combines formal and informal governance methods can enhance the effectiveness of these efforts. (Velazquez-Romera, G. 2017).

Transparency and open access to data ought to be supplied via websites and apps, enhancing awareness and comprehension of how data is used. Smart city applications allow citizens to obtain a range of information and carry out activities such as settling expenses, finding public transportation, and monitoring energy usage. The key objective of a smart city is to enhance the quality of life of its citizens and foster economic expansion. (Xia et al. 2023).

Participation: Technology plays a pivotal role in promoting public participation and citizen engagement in governance matters, particularly at the municipal level. It requires the inclusion of citizens in decision-making processes and service design and involves the participation of stakeholders and the private sector (OECD, 2021; HEC Paris, 2021).

Citizen involvement is crucial for the success of public projects in smart cities. Clear and systematic citizen involvement is indispensable for the success of smart city initiatives. European city authorities highlight the significance of involving citizens and persuading them regarding the advantages and security of smart city programs (Calzada, 2018). Technology has a crucial part to play in enabling public participation. Tools such as e-democracy, e-participation, wikis, social networks, blogs, and online petitions enable citizens to share their ideas and opinions. Moreover, Internet-based reporting and complaints provide a transparent way of involving citizens in identifying and resolving problems. Collaborative service production, such as participatory budgeting aided by information and communication technologies, engages citizens in resource allocation at the local level, decision-making, and enables them to contribute to the development of intelligent and sustainable cities (OECD, 2021; Velazquez-Romera, 2017).

2.2.2.3 Mobility Support

Technological development in mobility aims to enhance the efficiency and quality of urban transportation services. This is achieved by improving the adoption of new mobility solutions and making the flow of people more efficient through effective management of available resources, such as public transport, taxis, and roads, alongside targeted infrastructure investment.

Smart mobility is a complex matter in metropolitan areas, which encompasses environmental and economic aspects. It demands the deployment of advanced technologies and responsible conduct from individuals. Information and communication technologies (ICT) are utilized in smart mobility to enhance traffic flow and gather citizens' feedback on livability and public transportation services (Benevolo et al., 2015). The objective is to attain more cost-effective, efficient, and ecologically sustainable mobility. Integrated multimodal transport represents a considerable challenge for cities and communities. However, the presence of ICT infrastructure can help regulate car and freight transportation and monitor pollution levels. This can be achieved through combining various forms of public and private transportation while also adopting novel transportation methods (e.g.,). The promotion of "smart mobility" necessitates the inclusion of electric vehicles (City, 2022a), hydrogen-fueled vehicles, autonomous vehicles, bike sharing, and car-sharing as focal points of a forward-thinking strategy.

Aiming to enhance the flow of individuals and goods within a city or community, it is essential to adopt a customer-centric and inclusive approach that caters to all citizens, businesses and visitors. This calls for the development of innovative, sustainable, and safe transportation systems, as well as soft mobility and sharing-based solutions that employ electric vehicles. Moreover, accessibility, a crucial determinant of mobility, should remain a top priority. Alongside this, factors such as population density and infrastructure availability should also be taken into consideration while offering a high-quality mobility service. Finally, mitigating the environmental impact is of paramount importance.

(Bee Smart City (2022); HEC Paris, 2021).

The objective of SDG 11 is to render cities inclusive, safe, resilient and sustainable, with an emphasis on enhancing urban transportation systems (Griffiths et al., 2021).

Clean and not motorized options are essential components in addressing challenges such as pollution and non-motorized mobility within cities. Priority should be given to promoting public transport, demand management, and land-use planning to reduce traffic while facilitating walking and cycling. In addition, it is essential to introduce measures to promote clean energy in transit and parking, including multimodal transport at the individual level, electric vehicle infrastructure, and policies supporting clean, non-motorized alternatives.

Urban transformation may enable the adoption of sharing models like ride sharing, car sharing, and home sharing, leveraging new infrastructure to promote a sharing-based economy. This could promote improved social fairness and inclusivity within urban areas (Velazquez-Romera, 2017; HEC Paris, 2021).

There is clear policy attention on intelligent and eco-friendly approaches, for example, the application of smart parking and electric vehicles (EVs). Studies indicating the potential of lithium-ion batteries for smart city expansion stress the importance of eco-conscious materials for EVs. Promoting clean and sustainable mobility is vital in tackling challenges like pollution and non-car mobility in urban areas. A more livable and sustainable urban environment can be created through a combination of incentive policies, appropriate infrastructure, and sharing models (Velazquez-Romera, 2017; HEC Paris, 2021; Razmjoo et al., 2022).

Priority should be given to non-motorized options within the city. Conventionally powered vehicles must be phased out from the urban environment. Moreover, there should be efforts to promote public transportation, reduce traffic volumes through demand management and land-use planning, and facilitate walking and cycling.

Integrated ICT: Given the increasing trend towards integrated mobility, multiple studies endorse the significance of integration (ICT) in transportation. It pertains to a centralized platform that consolidates information from different modes and is anticipated to aid and reinforce travelers during their journey in the "pre-trip,", "on-the-road," and "on-board" phases, incorporating functions like trip planning, booking, and real-time information (Kamargianni et al., 2016).

ICT infrastructure comprises both hardware and software required for exchanging information among actors and between them and the physical environment of the city. The latter includes data acquisition systems (monitoring and positioning systems) and protocols for data communication (e.g., between traffic control centers and vehicles). Technical abbreviations will be defined upon first use. In addition, data quality is a crucial aspect, with a focus on the accuracy and timeliness of data. This data can be derived from parking sensors, parking information, and NFC payments (Velazquez-Romera, G. 2017).

The aim is to establish an effective public transport network, incorporating "mobility hubs" that serve as linkages between various modes of transport, whilst concurrently enhancing modes of travelling around the city and minimizing CO2 emissions (HEC Paris, 2021, p. 49).

2.2.2.4 Knowledge of the Population

The significance of technology in a smart city underscores that mere technological advancement alone is insufficient to render a city smart. In fact, the education level of the populace assumes critical importance (Sánchez-Corcuera R, Nuñez-Marcos A, Sesma-Solance J, 2019). It is essential to focus on educating and informing the public, changing the way citizens interact with the public and private sectors as individuals or businesses. This is vital in creating both social and digital inclusion and ensuring digital equality through educational programs (Bee Smart City (2022), HEC Paris, 2021).

The context of data-driven smart solutions for urban processes and practices prioritizes environmental and economic goals over social goals. (Bibri and Krogstie, 2020). Smart solutions must be distributed

fairly and meet the diverse needs and expectations of urban populations. This poses challenges and invites criticism. It is vital to balance economic and environmental goals with social goals to ensure urban sustainability that is both equitable and inclusive.

Giffinger's model (Giffinger et al., 2015) emphasizes a dimension that prioritizes citizens and their active involvement in smart cities. This encompasses fair and inclusive access to technologies, digital literacy, education and training, promoting diversity and social inclusion, as well as empowering citizens to take part in city life, influence decisions, and benefit from opportunities provided by smart technologies (Shamsuzzoha et al., 2021).

Environmental and economic objectives take priority over social objectives when implementing data-driven smart solutions for urban processes and practices (Bibri and Krogstie, 2020). However, this can result in challenges and criticism when ensuring equitable distribution of these solutions that cater to the needs and expectations of all urban population segments. Therefore, it is essential to balance environmental and economic objectives with social objectives to promote inclusive and equitable urban sustainability.

UN-Habitat's program for People-Centered Smart Cities, launched in 2020, acknowledges the potential of digital technologies to transform sustainable urban development. The program provides strategical and technical assistance to national, regional and local governments for digital transformation. (Centering People in Smart Cities | UN-Habitat).

The press conference titled "Cities 2030, Cities for All: Implementing the New Urban Agenda" was held during WUF9 in 2018 and was attended by representatives from 169 countries and over 19,000 participants. The conference highlighted the objective of promoting inclusivity and ensuring that all current and future residents can live in and contribute to cities and communities that are just, safe, healthy, accessible, affordable, resilient, and sustainable without experiencing any form of discrimination. The development of policies and programs can be enhanced in terms of inclusivity and responsiveness to people's needs, provided that a framework is established, wherein individuals are at the core of smart city development (WUF9, 2022).

SDG 4 and SDG 9 align with the understanding of individuals regarding how technology can assess them.

Digital Education: it encompasses both the utilization of technology to enhance learning methods and the development of individuals' technological proficiencies, thereby promoting academic excellence and equal opportunities at all levels of education and training.

This initiative encompasses educational programs and centers focusing on innovative technologies, the implementation of the internet in schools, the integration of technological devices in educational institutions and universities, the inclusion of programming in school curricula, and the promotion of new technological sciences in universities. Measures to facilitate long-term learning, such as fee reductions, are also being considered. Other methods encompass e-learning courses and the integration of ICT in learning environments, for instance, interactive whiteboards and e-learning platforms (Velazquez-Romera, 2017).

Digital education addresses numerous social challenges such as unemployment and social inequality. It can also foster innovation whilst pursuing an environment conducive for the development of inclusive smart cities. With universities, industry and government joining forces, smart cities can be realized.

A pivotal element of digital education pertains to the significance of universities in equipping citizens with the requisite competencies for smart cities, as well as fostering entrepreneurial and collaborative citizens. In managing data and technologies within smart cities (Kummitha, 2019), human skills prove to be crucial.

The key objective of digital education is to enable citizen comprehension and involvement by endorsing empowerment, co-creation, and bi-directional communication (Noori et al., 2020).

Inclusive society: Accessibility and inclusion are fundamental aspects of smart cities that guarantee accessibility of technologies to all citizens, irrespective of their age, ability, or socioeconomic status. (Shamsuzzoha et al. (2021) aim to promote equality of opportunity, reduce inequality, support the disadvantaged, and ensure equitable access to education and safety services. These components are essential to ensuring efficient social cohesion and an inclusive community within smart cities (Quijano-Sánchez et al., 2020). Technology plays a significant role in discovering creative solutions to prevailing social issues. Digital tools, like mobile applications for healthcare, education and transportation, enhance accessibility and effectiveness of vital services for the public. Furthermore, communication technologies speed up the connection between citizens and institutions, which leads to active engagement and participation in civic life. Nevertheless, it is pivotal to realize that technology in isolation is not the sole decisive factor in establishing smart cities. Other important elements comprise the involvement of citizens, sustainable urban planning, and inclusive public policies. Achieving social cohesion necessitates a comprehensive outlook of the entire urban ecosystem; technology serves as a means to enhance citizens' standards of living, but not as the solitary solution (Velazquez-Romera, 2017; Malek et al., 2021). There may be challenges associated with excessive use of technology, including greater social disconnection among individuals, concerns over data privacy and security, and the potential marginalization of people who are less digitized. Furthermore, if technology is not implemented equitably and inclusively, it could exacerbate social inequalities. To tackle these issues and advance social inclusion, it is essential to create public policies that support technology uptake and accessibility in a fair manner for all citizens. These policies ought to guarantee clear and collaborative management when defining the smart cities' technology development strategies (Malek et al., 2021).

Embrace creativity: The study undertaken by Quijano-Sánchez et al. (2020) underscores the significance of advocating for creative processes to enhance the welfare of the urban community and improve the economic productivity of cities. To accomplish this, promoting the endeavors of local artists and creative businesses, encompassing the cultural, media, art, advertising, and other sectors, is paramount. Furthermore, developing partnerships between these industries and universities, local authorities, and ICT companies can serve as a potent method to stimulate innovation.

Velazquez-Romera (2017) stresses the importance of creativity and innovation in the branding strategies of smart destinations. In other words, promoting and encouraging creativity is integral to establishing a unique and distinctive identity for a smart city, thereby attracting both visitors and residents. Additionally, creativity is deemed an endogenous factor in the identity of smart destinations. This infers that the creative potential of the individuals who reside and operate in the city comprises an inherent component of its image and allure. In essence, the ingenuity of the populace helps mould the identity and perception of the intelligent city.

Trinchini et al. (2019) acknowledge creativity as a key driver for the development of smart cities. Therefore, promoting creativity means enhancing the dynamism and vitality of smart cities. The instruction, learning, and knowledge play a central role. A higher education institution and a well-educated workforce attract creative people and contribute to rapid urban growth.

This demonstrates the importance of investing in intellectual resources to foster sustainable and knowledge-based growth. Smart cities can attract an emerging creative class, as suggested by Albino et al. (2015). This attraction creates a virtuous circle in which the presence of intelligent and creative individuals contributes to and benefits from the city's social capital, leading to a constant improvement and development of the smart city.

The adoption of creativity is pivotal to the triumph of smart cities. Fostering creativity across several aspects of urban living from production processes to branding strategies fosters vibrant, innovative, and enticing smart cities for the populace and visitors alike. Furthermore, promoting a people-centric approach and investing in education and knowledge are fundamental components for supporting the establishment of smart cities based on collaboration and creativity.

2.3 SUSTAINABILITY

Today, smart city development is a worldwide phenomenon that aligns closely with the United Nations' (UN) 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals, as listed by the Department of Economic and Social Affairs in 2019. One of these goals aims for an inclusive, safe, resilient and sustainable city. The Sustainable Development Goals strive for long-term benefits and encompass various aspects of smart and sustainable cities, as highlighted by Shamsuzzoha et al. in 2021.

A more intelligent index for the environment leads to a more intelligent economy. Therefore, the preservation of air and water quality and effective waste management lead to smarter environments and consequently smarter economies. A 50% or 75% increase in the smart energy index would result in a more intelligent economy (Abu-Rayash & Dincer, 2021).

2.3.1 Smartcities Sustainability

The significance of sustainability in smart cities and the vital function of technology in promoting a more environmentally sustainable transition is a subject of extensive study. Upon scrutinising the keyword 'smart sustainability' on ScienceDirect, it is evident that the importance of sustainability in cities has been a subject that has generated a notable level of interest in recent times:

Keyword: smart sustainability

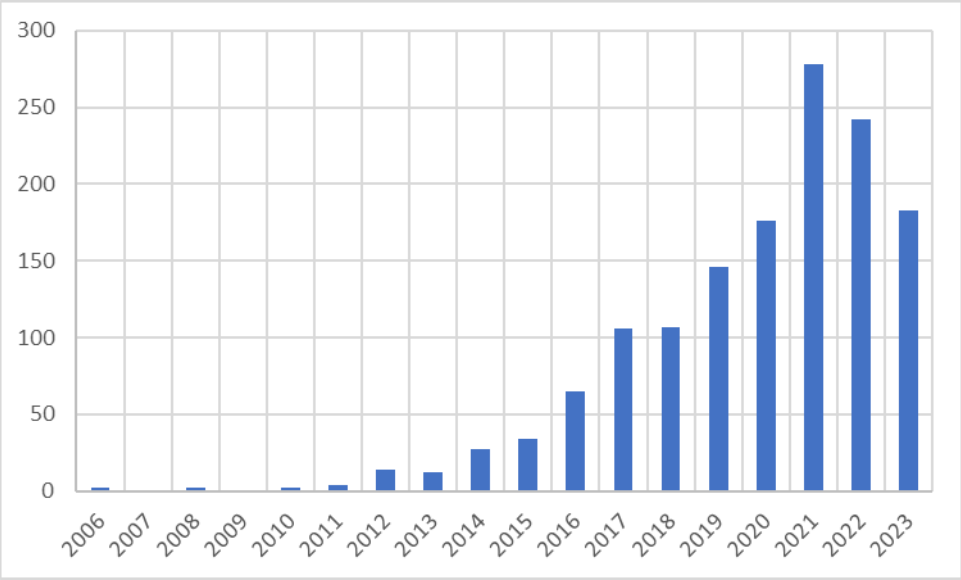

Figure 2.3: Number of publication with keyword: smart sustainability, Source: (*Smart Sustainability - Search | ScienceDirect.com*, Jul 2023).

The table depicts a substantial study into sustainability publications over the years, with a significant increase up to 2021, coinciding with the pandemic-induced lockdowns across the globe, followed by a subsequent decline. Notably, the publications in 2023 have already exceeded those from 2020 in just the first half of the year.

Smart cities must be developed objectively to address the challenge of decreasing CO2 emissions and meeting energy demand. This involves the increased use of renewable energy, transport energy efficiency, smart and energy-efficient buildings, and the development of smart infrastructure (Razmjoo et al. 2022). Technology, a fundamental component of Smart Cities, facilitates efficient energy management through the deployment of Smart Grids, contributing to a decrease in energy consumption and the reduction of greenhouse gas emissions. In addition, cutting-edge energy storage technologies, including batteries and mechanical rotating devices, are essential for ensuring a dependable energy supply in Smart Cities. Looking to the future, achieving a sustainable Smart City with high living standards and a positive impact on the environment relies on the electrification of domestic, industrial and transport systems (Almihat et al., 2022).

Smart Cities and Sustainable Cities are two important perspectives in modern urban development, but their focus can differ. Smart Cities emphasise "intelligence" and the implementation of modern technology to enhance service efficiency and engage citizens. Nonetheless, they often overlook environmental indicators in favour of social and economic ones. In contrast, sustainable cities place greater emphasis on balancing environmental, social, and economic aspects, with a goal of sustainably using resources and reducing CO2 emissions. It is crucial to integrate sustainability into smart city projects to ensure that environmental objectives are sufficiently addressed (Ahvenniemi et al., 2017b).

2.3.1.1 Green Building and Passive Houses

Green buildings and passive houses are two complementary approaches to designing and constructing sustainable buildings. The sustainability of a building is closely tied to the use of the most advanced technologies and methods to minimize environmental impact and resource usage over the building's life cycle, as well as ensuring a healthy and comfortable environment for occupants (Velazquez-Romera, 2017).

Green buildings are facilities engineered to minimise environmental harm by employing sustainable solutions and environmentally friendly materials. This can encompass the installation of photovoltaic panels to generate renewable energy and the incorporation of natural resources in urban environments. Consequently, these constructions make a noteworthy contribution to annual building energy efficiency and CO2 emissions reduction (Phap et al., 2021; Razmjoo et al., 2021). Some features of green buildings comprise centralized energy systems, monitoring energy consumption through Internet connection, policies aiming at reducing energy consumption, and renovation of buildings to enhance their energy performance. Challenges related to green buildings incorporate saving energy and adopting a holistic approach to environmental and energy concerns, along with pollution management (Velazquez-Romera, 2017).

On the contrary, passive houses are structures that seek to reduce heat flow through the building envelope, guaranteeing optimum thermal comfort and minimal energy consumption during their life cycle. Compared to green buildings, they provide superior indoor comfort. Furthermore, architects can design them as per their preference, even in the most extreme climates. (Schnieders et al., 2015). Passive houses prioritise thermal comfort technologies, energy-efficient solutions, environmentally sustainable materials and software-aided design. They can reduce heating demand by up to 89% compared to green building districts, making a significant contribution to achieving carbon targets and carbon neutrality (Han et al., 2022).

Green building and passive house initiatives are crucial in contributing to the Sustainable Development Goals, SDG 7, SDG 9, SDG 11 and SDG 13. Green buildings and passive houses are instrumental in decreasing energy consumption, supporting renewable energy, lessening the effects of climate change, and producing sustainable and habitable cities (Goubran, 2019).

2.3.1.2 Green energy

Green energy, derived from renewable sources such as the sun, wind, water and biomass, is pivotal in the transition to a sustainable future (Velazquez-Romera, 2017). Its benefits extend beyond energy generation.

To begin with, it mitigates carbon dioxide and greenhouse gas emissions, thereby helping to address climate change and protect the environment (Phap et al., 2021). Furthermore, sources such as solar and wind energy do not produce harmful air pollutants, enhancing air quality and advancing human health. Renewable green energy reduces reliance on fossil energy sources, thus averting the threat of resource depletion (Li, Z. 2023).

Furthermore, it encourages energy self-sufficiency for nations because it can be generated locally from sustainable sources. The green energy sector generates employment opportunities in fields like solar panel installation, wind turbine maintenance, and research into sustainable technologies, contributing to economic growth (Phap et al., 2021).

Technology plays a crucial role in promoting green energy. It addresses the variability of renewable sources through advanced weather forecasting systems and balances energy supply and demand (Li, Z. 2023). Moreover, technology assists in reducing upfront costs by innovating the design and production of green technologies. Also, the identification of appropriate sites and development of environmentally friendly technologies mitigate environmental impact.

The requirement for energy storage to handle the intermittency of renewable sources is resolved via sophisticated storage solutions, such as thermal storage, batteries, and green hydrogen (Velazquez-Romera, 2017). This technology bolsters effective use of space and integration into the electrical grid, guaranteeing stability and security (Phap et al., 2021).

Green energy is a critical means of achieving sustainability, made possible by renewable resources coupled with optimized, cutting-edge technology. Efforts to utilize these sources while reducing environmental impact are aided by technology.

Green energy is strongly associated with the SDGs, especially Goal 7 and Goal 13. The utilization of sustainable energy and energy efficiency helps to reduce greenhouse gas emissions and combat climate change. Additionally, green energy enhances energy security, diversifies energy sources and fosters the creation of sustainable communities (Almalki et al., 2021).

Of fundamental importance are **Smart Grids**, which are an advanced network that integrates generation, distribution, and renewable energy with ICT technologies. They optimize energy, reduce losses, and integrate renewable sources through transparency and bidirectional flow of information, involving consumers in energy decisions (Almihat et al., 2022). Smart Grid 2.0 aims to decarbonize, decentralize, and digitize the energy system by utilizing ICT, AI, and 5G. This evolution creates a digital and efficient energy network, reducing emissions and promoting micro-grids for local autonomy (Consortium Singapore, 2018). Smart grids represent a crucial step towards a sustainable future, improving efficiency and resilience (Almihat et al., 2022).

In Singapore, the Smart Grid system is highly dependable and sturdy, thanks to the integration of intelligent components in both the generation and transmission network. A distinguishing feature is the choice to have a significant part of the transmission and distribution network underground, resulting in grid losses of only about 3%. Singapore's objectives for its power system incorporate generation of clean energy, energy efficiency, and grid resilience. These objectives are further bolstered by vigorous research and development (R&D) and the construction of financially feasible microgrids, as well as the widespread use of distributed energy resources. Data and prognostications illustrate the escalation of electricity usage in Singapore, along with the triumph in curtailing grid losses and enhancing the typical length of power interruptions for patrons (Consortium Singapore 2018).

In Barcelona, the Smart Grid system implements intelligent, data-driven solutions to optimize production, consumption, supply, and energy facilities. Smart meters, intelligent appliances, and efficient energy resources are implemented. The MONICA Project in Barcelona was developed for real-

time monitoring and evaluation of the electricity distribution network (Monica Project: Smart Grids - E-distribución, n.d.). Medium- and low-voltage sensors record crucial measurements to evaluate the state of the network. Real-time data is collected through sensors and smart meters to diagnose issues and enhance the network's performance. Smart grids in Barcelona offer many benefits, such as providing decision support for energy generation and supply based on actual demand, optimizing energy distribution networks, real-time monitoring and analysis of energy consumption and greenhouse gas emissions, managing distribution automation devices and preventing power outages through dynamic pricing models for energy use (Bibri and Krogstie, 2020).

2.3.1.3 Green Urban Planning

Green urban planning, which aims to create sustainable cities using urban planning and restructuring policies, is a crucial approach. This strategy involves adding green areas, such as parks and urban forests, into existing urban spaces to improve inhabitants' quality of life and prevent adverse consequences of urbanization (Baycan & Nijkamp, 2012). Green urban planning aims to create accessible, compact, and transport-oriented urban environments, which is related to the previously explained chapter on mobility.

Technologies like RS, GIS, and computational fluid dynamics (CFD) simulation play a vital role in supporting this planning. These technologies allow for the evaluation and enhancement of green spaces, pinpointing areas for improvement and directing the formation of urban ecological networks (Wang, 2022).

Furthermore, the developing idea of data-led intelligent cities applies urban computing and artificial intelligence to enable strategic and integrated planning (Bibri, 2021), providing resources for well-informed decisions and streamlined oversight of green spaces.

Difficulties such as energy conservation, contracting cities, a comprehensive approach to the environment and contamination necessitate pioneering methods. Green urban planning, supported by technology, tackles these challenges to develop more sustainable and resilient cities. By incorporating concepts such as car-free planning and citizen participation through data, cities can transform into hubs of smart technology, where sustainability and technology converge to create cutting-edge urban environments.

2.3.2 Smart Environment

The Sustainable Development Goals provide a comprehensive framework for assessing the sustainability of smart city initiatives. Several studies (e.g., Kramers et al., 2014; Bibri, 2018) highlight the potential for smart cities to contribute towards the SDGs, particularly in areas such as clean energy, sustainable cities and communities, and responsible consumption and production.

'Smart Environment' refers to the methods employed by local governments to regulate and improve the built and natural surroundings, in order to enhance the quality of life for residents and tourists.

Advanced technologies and creative approaches assist in enforcing sustainable standards and traditions, enabling better governance and cultural changes.

Reducing waste production, monitoring and managing pollution, reducing emissions, managing water, achieving energy efficiency, and accelerating the local energy transition are among the key objectives of 'smart environment' initiatives (Bee Smart City (2022)).

Enhancing environmental protection highlights the importance of increasing green spaces within urban areas, limiting soil artificialization, and reducing the carbon emissions of pre-existing buildings. It is necessary to acquire a fresh set of skills and competencies at the municipal level. These abilities are encompassed by Sustainable Resource Management. Reducing the sources of pollution ameliorates the allure of the city's innate conditions. (HEC Paris, 2021, p. 35).

2.3.2.1 Water management

Water management is a complex undertaking that encompasses the planning, development, distribution and conservation of water resources to meet the needs of various sectors and promote sustainable usage. This involves assessments of supply, quality, infrastructure, and potential water hazards. With mounting challenges such as scarcity, climate change, and heightened demand, water management is of paramount importance (Jódar-Abellán et al., 2019).

Water diplomacy refers to political processes aiming to resolve water-related disputes between neighboring countries, by means of diplomacy to establish shared governance arrangements and encourage collaboration (Hossain, 2013). This perspective values cooperation and negotiation as essential components for the effective management of complex water networks and conflicts of water use. Recent research indicates that diplomacy is crucial in preventing and resolving transboundary water-related conflicts (Sehring et al., 2022).

To tackle these obstacles, sophisticated water management systems have been created using state-of-the-art technologies like the Internet of Things (IoT) and data analytics to enhance distribution, supervise quality and enhance water efficacy (Gade, 2021; Aldegheishem et al., 2022). This inventive approach, dubbed smart water management system.

One of the strengths is its capacity to facilitate effective water distribution and control, resulting in noteworthy water conservation and waste reduction. Through the utilization of real-time data collected from sensors and meters, the system can detect water usage, identify leaks and optimize circulation in accordance with demand (Mishra et al., 2022). A comparison of case studies enhances our understanding of how these systems adapt to varying urban realities and water challenges. This could lead to improved management strategies in different contexts.

2.3.2.2 Waste management

Waste management constitutes a crucial component of urban sustainability and is paramount to the development of smart cities. Despite impressive technological advancements, it has not kept up with the pace and evidence of citizen discontent with waste management services in smart cities abounds (McCurdy et al., 2018).

Comparing waste management practices needs the consideration of several factors. Public perception and citizens' perspectives on waste management services are crucial as they can influence trust levels in the system and its ability to tackle waste-related challenges. If citizens regard waste management services as efficient, reliable and environmentally friendly, they are more likely to participate in sustainable practices, such as separate collection and recycling. On the other side, if citizens perceive that services are lacking, ineffective or harmful to the environment, they might be less inclined to participate in and back waste management policies. The citizens' perspective is just as vital as it represents the viewpoint of the end-users of waste management services. They can offer valuable insight into their requirements, preferences and worries regarding waste management. Their involvement can help to identify areas for improvement, discover innovative solutions, and encourage the adoption of sustainable practices. Moreover, when citizens are involved in planning and implementing waste management policies, this can promote a feeling of shared responsibility for caring for the environment and the local community (Braga, 2021). Liao et al. (2020) argue that involving citizens in critical activities without added value can lead to waste.

The significance of non-value-added critical activities and the resulting wastefulness within waste management lies in the necessity to maximize resources and enhance the efficiency of the waste management system. Such activities do not contribute to adding value in the waste management process and may involve squandering time, funds and resources. Critical activities that do not add value may comprise of inefficient processes, task duplication, insufficient coordination between various stages of waste management, and inadequate stakeholder involvement (Paletto et al., 2017). These

activities can impede the waste management process, enhance costs, and decrease the system's overall efficiency, leading to food wastage behavior (Grandhi & Singh, 2015).

2.3.2.3 Air pollution

Air pollution refers to the existence of harmful substances, such as particulate matter, gases and pollutants in the atmosphere that can negatively impact human health and the environment. These can arise from various sources, including industrial emissions, vehicle exhausts, as well as natural sources like dust and pollen. The detrimental effects of air pollution on human health have been extensively researched, with studies indicating a correlation with cardiovascular disease, respiratory disorders, and other adverse health outcomes (Münzel et al., 2018; Hansel et al., 2015 etc.).

The data from WHO indicates that almost the entire global population (99%) inhales air exceeding the WHO's recommended standards, which contains substantial pollutants. The highest levels of increased exposure are encountered in less developed countries. The combination of household air and ambient air pollution is associated with 7 million premature deaths each year (World Health Organization; WHO, 2019).

When examining case studies on air pollution, it is imperative to consider various factors. Initially, the origins of air pollution in every city must be pinpointed and evaluated. These consist of manufacturing activities, transportation systems, and other human-made factors that add to pollution levels. Furthermore, it is vital to consider the geographical and meteorological traits of cities, which might affect the spread and build-up of pollutants (Myeong & Shahzad, 2021).

Air pollution is known to impact various SDG goals.

SDG 3 is achieved by improving air quality since it is vital to prevent diseases and promote good health, SDG 11 can be achieved by reducing air pollution since this will create sustainable and healthy urban environments, also reducing air pollution can contribute to global efforts to tackle climate change and achieve Goal 13.

Besides, air pollution can adversely affect terrestrial and aquatic ecosystems, which can hinder progress towards achieving Goal 15.

As a means of comparison the data presented by IQAir, a company committed to monitoring and disseminating details about air quality, will be utilized. The firm collaborates with a vast network of associates including government agencies, non-profit organizations, research institutes and individuals to collate data on air quality worldwide. This information is then utilized in generating interactive maps and proffering comprehensive intel on air quality in diverse regions.

IQAir's network of contributors is substantial and encompasses many government agencies, not-for-profit organizations, educational institutions and individuals. These contributors supply crucial data to evaluate air quality in diverse regions of the world (IQAIR, 2023).

The company has developed the Air Quality Index (AQI), a standardized measure of air quality that considers pollutant concentrations and other indicators like the yearly average concentration of particulate matter or the number of days surpassing specific pollutant thresholds (Myeong & Shahzad, 2021; Hansel et al., 2015).

3 Methodology

Research methodology is a pivotal element in composing a master's thesis as it furnishes systematic guidance for planning, executing, and dissecting the study. This chapter presents the primary methodology sectors applied in the creation of this thesis, focussing on qualitative case analysis.

It is imperative to choose a research methodology wisely in order to progress the composition of a completed master's thesis. The methodology chosen will dictate the data type that will be accrued, the analysis instruments employed, and the interpretation of the outcome. For this thesis, we have embraced a qualitative method founded on case analysis.

This represents a qualitative research methodology that strives to comprehend a particular phenomenon in a specific time and place. This approach enables researchers to gain a comprehensive understanding of the phenomenon being investigated by examining the underlying factors and mechanisms that contribute to the similarities and differences between cases (Lintz, 2017).

3.1 Case Study Methodology

Case studies methodology is utilized extensively in social, educational, clinical, and business research. The studies concentrate on comprehending and evaluating various elements of a particular research issue. In general, the research design employs qualitative techniques, though quantitative approaches may occasionally be employed as well.

The method permits the thorough examination of a specific topic, such as an individual, group, place, event, organisation, or phenomenon (McCombes, 2023). This technique proves particularly advantageous in outlining, contrasting, assessing, and comprehending the detailed nuances of the phenomenon in question.

This type of analysis represents a valuable tool in researching complex phenomena in their respective contexts. Several authors, including Yin (2003), Gerring (2016), and George and Bennett (2005), have significantly contributed to this methodology.

The research method focuses on analysing a phenomenon or case within a particular context of time and place, providing researchers with a comprehensive understanding of the entire phenomenon under study (Cope, 2015).

It requires a systematic, structured process to ensure research rigour and reliability, from planning through to the final analysis and data interpretation (Lewis, 2015).

The design is commonly used in qualitative social science research and aligns with the constructivist paradigm which sees truth as relative and dependent on individual perspectives (Baxter and Jack, 2008;

Simons, 2008). The distinctive characteristic of qualitative case studies is their emphasis on exploring and elucidating the impact of context on a phenomenon (Cresswell, 2007; Yin, 2009).

These studies engage in meticulous and comprehensive examination of the selected case(s), frequently necessitating the assembly of data from various sources (Yin, 2009; Thomas, 2011).

Two crucial factors determine the selection of a case for a case study: the representativeness of the study unit (which can be an individual, place, group, organisation or other) and the relevance of the case characteristics to the research question (Thomas, 2011).

There are numerous qualitative case study variations, including single and multiple cases. Stake's (1995) classifications distinguish between collective, instrumental and intrinsic cases. Additionally, Yin's (2012) categories consist of descriptive, explanatory, exploratory and evaluative cases.

The absence of a standardised process has resulted in a difficulty in establishing the features of case studies, which has led to complications in creating such studies (S. Almaki, 2016). Nevertheless, it should be recognised that there is no sole, conclusive technique for performing research and the selection of the method ought to depend on its appropriateness for the task and the researcher's abilities (Tashakkori & Teddlie, 2010; Buchanan & Bryman, 2009; Wilkinson & Birmingham, 2003).

3.2 CASE STUDY STRUCTURE

The case study methodology is designed based on the literature review and methodology discussed earlier. To conduct a thorough literature review, we consulted several bibliographic databases and searched for relevant keywords such as 'smart city', 'smart sustainability', 'smart governance', 'smart economy', 'smart traffic', 'smart mobility', 'smart technology', 'smart living', and their equivalents.

After establishing the context and research question, a specific search was conducted to locate pertinent studies. Initially, attention was directed towards the economic and sustainable evaluations of smart cities in general, and later transitioned to an analysis of case studies. The exploration was carried out via academic search engines like Google Scholar and online databases like JSTOR and ScienceDirect, among others.

The case studies on Barcelona and Singapore were chosen according to specific inclusion criteria, such as economic dimensions, sustainability, technological development, and availability of policy data, considering their geographical location.

The objectives and research questions were then established by reviewing literature, video recordings of seminars and conferences, related documents, and reports. The significance and relevance of the studies were evaluated through consultation of reports and government documents, identifying possible economic and environmental consequences of smart cities. In instances where research gaps were identified in precise domains, documents obtained through academic search engines and mainstream journalistic sources were used, to sustain a balanced approach while not solely relying on impact factor.

3.2.1 Phases and Process of Analysis

The table below provides a comprehensive guide on the methodology for conducting a detailed analysis of the smart cities examined in this study. Each phase of the methodology was meticulously developed to direct the entire research process, starting from defining the research objectives to reaching conclusions and making recommendations in the final phase. This table presents a summary of the various stages and associated tasks, outlining the process followed to conduct a thorough investigation into intelligent urban centers.

The following graph illustrates the procedure to reach the intermediate goals that have been defined in Figure 2:

Figure 3.1: Methodological Phases

The table below outlines the various methodological stages that were meticulously planned and executed for this smart cities study. Each phase has a specific function in the research process and contributes to a comprehensive comprehension of the dynamics of the smart cities under investigation.

The Exploration phase focused on defining the objectives of the analysis and selecting appropriate case studies. which enabled us to establish a robust foundation for our study.

The Analysis phase thoroughly examined the existing literature, analyzed the current situation, and recognized the primary challenges connected with smart cities. This phase was critical in contextualizing the case studies within the wider landscape.

The Execution phase carries out a comprehensive analysis of the case studies, scrutinizing the data collected and exploring the precise dynamics of Singapore and Barcelona.

Finally, the conclusions section details our main findings, acknowledges the limitations of our study, and proposes recommendations for future research.

This table is a crucial reference for our methodological approach and serves as a valuable tool for tracking the progress of our smart cities research.

3.2.2 Definition of Analysis Factors

During the preparation phase of the research, once the literature review has been completed, we can clearly and precisely define the three significant factors that will constitute the heart of this investigation. This study is intended to answer the three principal questions set out in section 1.2 Objective, and to accomplish this, we require a structured and unbiased approach. The literature review played a pivotal role in influencing our comprehension and selecting the most pertinent factors for our case study.

The parameters we have identified serve as objective benchmarks, providing a basis for evaluating and comparing the cities subject to this study. These parameters form the foundation of our analysis, guiding our research to uncover significant connections and emerging trends.

Therefore, based on the results of our extensive literature review, we have identified the following three key factors that will be the focus of our case study:

Economics: analysis within a smart city is not solely focused on historical and current economic prosperity, but also emphasises the necessity to adjust the economy towards a more ingenious and sustainable model. This involves examining conventional indicators while prioritising how economic development can facilitate a prosperous transition to globalisation without jeopardising economic performance. The objective is to balance economic growth with long-term sustainability.

Technology: is the catalyst for smart cities and is integrated into every realm of urban life. The obstacle rests in ensuring technology is employed inclusively and favourably for all inhabitants. The assessment of technological factors centres on the uptake, advancement and execution of technological remedies that enhance the effectiveness and standard of living in cities. This encompasses scrutinising how technology can impact mobility, security, accessibility to public services and beyond.

Sustainability: is becoming a fundamental principle of smart cities, as it aims to alleviate current and future global threats and enhance the quality of urban environments. The assessment of the environmental impact of urban decisions, the management of resources and enhancing energy efficiency are the focal points of sustainability analysis. This represents the aspiration to establish an equilibrium between the needs of present and future generations for a healthier urban space.

In this research, the comparative analysis of voluntary and international reports provided by the study cities was conducted using key metrics in order to assess the cities' adherence and progression towards achieving SDGs. These targets were selected to reflect the wide range of challenges and sectors that the SDGs cover, as well as to provide a comprehensive picture of cities' commitment to sustainable progress. The case analysis is conducted based on scientific papers, official press releases from non-governmental organizations, governments, universities and companies. This paper will use primary and secondary documents to analyze the case studies. Two cities are analyzed and compared based on the defined factors. These are Singapore, representing the Asian continent, and Barcelona, representing the European continent is an emerging smart city that is becoming.

at the beginning of each section, including why this market was chosen for this case study. The aim of this approach is to obtain a broad and multifaceted view of the complex issues concerning the sustainability and evolution of smart cities in the case study. The factor analysis is followed by a discussion of the results of each case. The discussion questions the evolution of smart cities by analyzing their performance.

Below is a more detailed tables of the factor analysis:

Table 3.1: Economical metrics and assessments

sub-sub-factors	Metrics Singapore	Assessment Singapore	Metrics Barcelona	Assessment Barcelona
Entrepreuneship and innovation	Number of Start-ups Number of Unicorns Number of Investors, Incubators, and Accelerators PCT Applications Number of Scientific Publications Public Investment in R&D Distribution of Number of Establishments by Sector of Activity Tax Rates for Businesses and Individuals	Global City Index Ranking Top 100 S&T Clusters Ranking Employment Gains through 'Adapt and Grow' Business Establishment Time Global Competitiveness Index	Number of Unicorns Investment Levels in Startups Sectoral Allocation in Startups R&D Expenditure Patent Metrics Economic Diversification Total Entrepreneurial Activity (TEA) Rate Tax Exemptions and Rent Relief Investment in Economic Efficiency	Ranking Assessments Award Recognitions Public-Private Partnerships Social and Environmental Goals Governance of Economy Innovation Spaces and Programs Social and Solidarity Economy (SSE)
Productivity	GDP Growth Rate GDP in Chain Dollars (for 2015) Contribution of Services Sector to GDP GDP per Capita Unemployment Rate	Economy's Resilience Economic Policies' Effectiveness Importance of Productive Industry Effectiveness in Achieving Low Workforce Training and Tax Incentives for Job Creation Adaptability to New Technologies Sustainable Economic Growth	Growth Rate of Gross Domestic Product (GDP) Unemployment Rate investement public and private	Economic Development/Stability Efficacy of Economic Policies Effectiveness of Investments in Technological Innovation Presence in High Value-Added Sectors Employment in Technology-Intensive and Knowledge-Intensive Sectors
Local and global interconnectedness	GDP generated by external demand Strategies for Deepening and Diversifying Global Relationships Investments in the transport sector Expansion of rail network Mobile phone penetration rate Wireless broadband penetration rate Financial ratings (AAA rating) Efficiency in export and import processing times Customs efficiency score Growth of stock market Service exports	Importance of physical infrastructure in global and local interconnection Digital readiness Strategic importance as Southeast Asia's largest port and global financial hub Comparison of efficiency against Southeast Asian average Resilience and efficiency Positioning as a prime destination for investors and entrepreneurs Initiatives to unite entrepreneurial ecosystems	Allocation of Municipality's Resources Number of Collaboration Schemes Sanctioned and Executed Number and Percentage of Foreign Workers in Catalan Startups Number and Percentage of Startup Founders from Other Countries Percentage of Catalan Startups with Foreign Clients Average Revenue from Foreign Clients Global Cities Investment Monitor Ranking fDi Intelligence Rankings EY Attractiveness Survey Europe Ranking European Cities and Regions of the Future Ranking	Global City Index Ranking Alignment SDG 17.2 "Barcelona Plan, Global City: Master Plan for International Relations 2020-2023" Number of Collaboration Schemes Global Justice Education Strategy Interview with Bria Diversity and International Attractiveness of Startup Sector

Table 3.2: Technological metrics and assessments

Safe	Community Collaboration Technology Deployment (e.g., Drones, Surveillance Cameras, Intelligent Transport Systems) Survey: Public Opinion Percentages Concept and Prototype Creation by Students HDB implementing of camera	Sustainable Development Goals (SDGs) 6,3,11 Alignment Community Safety and Security Technology Initiatives Public Opinion Comprehensive Evaluation of Long-term Efficacy and Consequences	Ranking in Global City Outlook and safety index Implementation of Innovative Initiatives Healthy security Infrasctructure security ranking	Implementation of Innovative Initiatives Interviews with experts Global City Outlook Ranking Safe Cities Index 2021 Statista Reports BCN Smart City Initiatives ITU/UN tech agency reports on GDPR and blockchain technology
Cultural event	Number of Unique Cultural Occasions such as Festivals in Chinatown and ARTWALK in Little India	Collaboration with Chinatown Business Association and Little India Shopkeepers and Heritage Association for unique cultural occasions	Financial Influence of cultural event Number of Global Companies and Visitors Survey Results from the Institute of Culture in Barcelona Volontare report review initiative	Annual Economic Impact Significance of Technology in Organising International Events Contribution to City's Economy Competence in Incorporating Technology into Cultural Events Alignment of Cultural Offerings with Local and Visitor Requirements Local Community Engagement Youth Participation in Cultural Events
Healthy	Water consumption hospitals Employment Statistics in the Healthcare Sector	Alignment with UN Sustainable Development Goal 3 (SDG3) Healthcare Accessibility and Efficiency Health Infrastructure and Logistics During Emergencies Resource Management in Healthcare	Maternal Mortality Rates Neonatal Mortality Rates Prevalence of Sexually Transmitted Infections Rate of Premature Mortality Among Children Under Five Technological Utilization in Health	Achievement in Bloomberg Philanthropy competition Alignment with SDG 3 of the UN Progress in Reducing Maternal and Technological Responsiveness to Health Challenges and Emergencies Emergency Preparedness Plan

Smart tourism	analysis of volounteer report (Ministry of Foreign Affairs, 2018, HEC Paris, 2021, Von Richthofen et al., 2019, Rodríguez, 2023)	Definition of main initiative: Holistic and Multi-faceted Approach by Singapore Tourism Board (STB) Interplay between Tourism and Local Culture TIP-iT program Limitations in Tourism Industry Managing and Planning of Cultural Events (e.g., Formula 1 Grand Prix)	Employment impact of tourism Survey population perception of turism increase rent payment local number Airbnb apartment Average spending per tourist accommodation (Indicator 893A) Average spending per tourist per day (Indicator 893B) Ratio of tourist accommodation to resident population (Indicator 894)	Job generation in the tourism sector Regulatory fines and number of inspectors Rise in rents and pressure on popular areas Sustainable tourism management and Biosphere Platinum certification Infrastructure accessibility Public perception of tourism Temporal evolution of key indicators related to tourism Progress towards projected targets for 2030
Data transparency and open data	Number of Adaptable Datasets in 'Data.gov.sg' Number of Government Bodies Contributing Data to 'Data.gov.sg' Number of Datasets in Economic and Socio-Demographic Fields	Singapore's Alignment with SDGs (Goal 11 and Goal 16) Privacy and Data Security Concerns due to Emerging Technologies	Interview (ITU/UN tech agency, 2021) Number of Reusable Datasets (597) Distribution of Available Open Data Sets by Sector Number of Datasets in Each Sector	Dataset Accurancy Digital Sovereignty Administrative Transparency Digital Divide Digital Inclusion Digital Literacy
Participation	Number of Applications Aimed at Citizen Reporting Business-Centric Initiatives (Punggol Digital District)	Level of Citizen Involvement in Governance Effectiveness of Technologies in Engaging Citizens	Number of Datasets Level of Citizen Involvement in Decision-Making	Efficacy of Open Data in Active Citizen Participation
Clean and not motorized option	Percentage of Singaporeans Using Walking Percentage of Singaporeans Using Cycling Extent of Cycle Route Network Public Transport Usage Trend During COVID-19 MRT and LRT Average Daily Users	Ongoing Initiatives for Cycling Paths in Public Housing Towns Specific Area Expansions and Upgrades for Cycling Paths	Speed Limit superinsulated Percentage of City Covered by Bike Lanes Accident and Safety Monitoring Programs for Cycling Expansion of Bike Lanes (in km) Number of Registered Users of Bicing Service Percentage of All Internal Trips Made Sustainably	Effectiveness of Superisolates in promoting non-motorized mobility Effectiveness of Cycling Initiatives in Promoting Safe Mobility Social Acceptance of Bicycles as a Means of Transportation Overall Ranking for Sustainable Mobility Ongoing Evaluation for Emerging Challenges
Integrated ICT	MRT and LRT Average Daily Users Penetration Rates of Various Broadband Services	Alignment with SDG 11, 8	Number of Public Wi-Fi Points Volounteer report regarding initiative of improvement the ICT	Initiative regarding: Public Services Optimization Analytical Data for Public Transport System Economic Benefit Prediction Strategy Reassessment for Private Transport Services
Digital education	Government Subsidies towards Pre-School Education Discontinuation of Mid-Year Exams for Select Students Proportion of student with access to basic services proportion of youth and adult with ict skills by sex	SDG 4 alignment Proportion of Schools with Access to Basic Services Significance Placed on ICT Proficiencies	University Subject Incorporation Business School Rankings Number of University Students in the Metropolitan Area Enrollment in Master's and Doctoral Programs	overview of the academic backround level regarding economic principally Educational Quality and Ranking Implementation of Educational Initiatives Interdisciplinary Collaboration Educational Demographics Development and Human Rights
Inclusive society	Number of low-income households granted access to reasonably priced broadband Annual real change in average monthly household income from work per household member Income growth of households in the 1st - 40th percentile Alignment with SDG 8 (Decent Work and Economic Growth) Alignment with SDG 10 (Reduced Inequalities) Implementing from inititiatives.	SDG 8,10 alignment Effectiveness of Home Access initiative Impact of IM Silver programme Efficacy of People's Association's Academy for the Elderly (PASA)	Percentage of Population with Disabilities in Personal Autonomy Programmes AROPE Rate Prevalence of Loneliness Among Adults Number of Discrimination Complaints Percentage of Young Individuals in BCN Interculturality Program Percentage of 18–34-Year-Olds in Local Associations for Inclusion	Project Effectiveness Accessibility to Digital Services Personal Autonomy and Independent Living Programmes for Disabled Population Discrimination Complaint Handling Global Goals for Social, Economic, and Political Integration Inclusivity and Diversity for Young Adults
Embrace creativity	Proportion of Singaporeans attending a minimum of one arts or cultural event annually Financial contributions allotted for the Singapore Arts Plan (2018-2022) Number of grants and scholarships disbursed by the National Council for the Arts (NAC)	Implementation of 2012's Strategic Review on Arts and Culture (ACSR) Effectiveness of the Singapore Arts Plan (2018-2022)	Budget for the Neighbourhood Plan 2021-2024 Turnover of Core Creative Industry Earning from creative industries	Analysis og the initiative and the revenue impacting for the city Citizen Involvement in Urban Regeneration Turnover in Core Creative Industry

Table 3.3: sustainability metrics and assessments

Green Building and Passive houses	Percentage of Green Buildings by Gross Floor Area Number and Type of Projects in Carbon Capture, Utilisation and Storage (CCUS) total green building surface	Implemation expected from initiative and align with 2030 Agenda Type of Projects in Carbon Capture, Utilisation and Storage (CCUS) Transparency Metrics in Carbon Markets (Climate Action Data Trust)	Zero-emissions goal Energy preservation Intelligent waste management Water optimization Quality of life and social equity 30% reduction in energy usage Savings of over €36 million Expenditure on Sustainable Development Goal 7 square meters of residential space renovation LEED Certification	Barcelona's contribution to SDG 7 Effectiveness of intelligent lighting systems Expenditure ratio on energy efficiency in housing Allocation of municipal funds on sustainable infrastructure LEED Certification as an indicator of efficient water and energy usage Definition of the economical effort regarding passive houses Initiative zero emission
Green energy	SolarNova Initiative Energy Source Distribution Investment in Research and Development	smart grid project Singapore Green Plan 2030 Goals	Annual production of photovoltaic plant in kWh Annual energy needs of households covered by photovoltaic plant Number of electric and hybrid buses to be purchased Conversion rate of the public transport fleet to electric vehicles Budget for the PRIMA project spread over four years Ranking sustainable city in Europe	smart grid project Long-term strategy to eliminate dependence on fossil fuels Sovereign Energy Transition Plan Renewable Lighting Plan 2018-2020 Barcelona Energy Improvement Plan (PMEB) Use of renewable energy sources in public infrastructures Participation in the PRIMA project by IREC
Green urban planning	Analysis of volounteer report to define the major initiative EcoCampus Programme Goals Integrated Environmental Modeller (IEM)	Sustainability Awards Environmental Impact Minimization Carbon, Waste, Energy, and Water Reduction Targets Government Commitment to Solutions	Green Space per Inhabitant Investment in Green Areas (EUR) Number of Redeveloped Housing Units Number of New Affordable Housing Units Percentage of Public Housing Stock Budget for Barcelona Renewable 2030	Degree of Effectiveness of Private Sector Involvement Policies Social Impact of Sustainable Urban Initiatives Responsiveness to the Needs of Local Communities
Water management	Freshwater Availability Ranking Average yearly rainfall Water Consumption per Inhabitant in Individual Homes Water Consumption inhabitant Water Demand Served by Different Sources Efficiency of Wastewater Collection and Recycling (Deep Tunnel Sewerage System) Allocation for Water Sector R&D water consumption forecast	Necessity for Multifaceted Approach for Effective Resolution Susceptibility to Climate Change Competition for Water Between Domestic and Industrial Usage Utilization of Abundant Precipitation Influence of External Factors Efficiency of Resource Management via Technology Challenges Presented Objectives and Strategies for Addressing Challenges	Water Demand Available Water Sources Reservoir Capacity as a Percentage Increase in the Cost of Each Block in Progressive Block System Water Consumption for Industrial and Commercial Purposes Households in 'Water Poverty' Decrease in Water Consumption Technology in Percentage Savings in Currency	Water Supply and Demand Balance Vulnerability to Drought Pricing and Cost Impact on Consumption Household 'Water Poverty' Technological Innovations and Their Effects Water Consumption per Resident Trends in Water Consumption Over Time Efficiency of Water Management Policies Public Awareness and Behavior Change
Waste management	Total Waste Generation Quantity Recycled Quantity Disposed Recycling rate	Analyze the actual waste consumption and the implementing Sustainable Singapore Blueprint Environmental Protection and Management Act (EPMA) Define the Zero Waste Masterplan and the ambition of the agenda 2030	Reduction in municipal solid waste Target collection rate Per capita waste generation Number of lorries required for waste collection Total waste generated Total waste disposed of Energy recovery Recycling rate Composting rate Mechanical-biological treatment (MBT) Energy utilization levels	Effectiveness of the city's environmental policies and technological initiatives Assessment of progress made over the years Identification of areas that could benefit from further improvement Initiative
Air pollution	Annual Mean Concentration of PM2.5 24-hour Average Exposures of PM2.5 Number of Days Exceeding WHO 24-hour Limit Percentage Reduction in Road Traffic (Due to ERP) Fluctuations in PM2.5 Concentrations Comparison of Singapore, WHO, and EU Air Quality Standards Number of fixed air quality monitoring stations.	World Health Organization (WHO) Air Quality Standards European Union Air Quality Standards Pollutant Standards Index (PSI) Singapore Air Quality Index (AQI) Compliance with WHO 24-hour Restriction Compliance with EU Daily Exposure Limits Public Health Concerns	Number of fixed air quality monitoring stations PM 2.5 Levels Annual and 24-hour mean exposures of PM 2.5 3-Year Average of PM 2.5 Levels Online Portal Updates on Current Pollution Levels	Friends of the Earth's 'D-' Rating (2015) Analysis PM2.5 level against EU WHO guidelines European Commission Citation for Non-Compliance (2019) WHO Guidelines on PM 2.5 Levels (2021) EU Air Quality Standards Public Health and Well-Being Awareness

4. Case analysis

This chapter presents a comparative analysis of two major smart cities: Barcelona and Singapore. Through an in-depth examination of these cities, the goal is to identify smart aspects related to people, governance, life, mobility, environment, and economy. In addition, the analysis aims to highlight the strategies employed by these cities, comparing their approaches and providing any appropriate recommendations. In addition, international climate change guidelines and reports provided by the study cities will be combined.

4.1 BARCELONA

Barcelona, situated on the north-east coast of Spain, offers an outstanding example of urban transformation. As the capital of Catalonia and the second most populated city in Spain, it encompasses 1.6 million inhabitants within its municipal boundaries, extending to over 4.8 million in the metropolitan area.

The city gained the esteemed Smart City Expo World Congress Award in 2015, affirming its standing in the smart city arena (Morningstar, 2023). However, what makes Barcelona a compelling case study is its shift from a traditional smart city strategy to a pioneering paradigm that prioritises experimental initiatives and engages citizens proactively. This transformation acknowledges citizens' vital role not just as recipients, but also as decision-makers and active contributors in molding the city's destiny (Capdevila & Zarlenga, 2015).

Despite the economic challenges faced following the 2008 financial crisis, Barcelona has shown remarkable resilience and adaptability. As Spain's second largest city, it has become an industrial hub due to its concentration of knowledge, tourist appeal, and its major port. In 2011, Barcelona undertook an ambitious journey to become a smart city with the introduction of the Barcelona Smart City programme. The programme aimed to enhance citizens' quality of life and develop the city into a more sustainable and intelligent environment by utilising information and communication technologies (ICT). The city collaborated closely with local universities and top technology companies, creating a synergy between academia, industry and the public sector.

4.1.2 Economics

Barcelona was awarded the prestigious iCapital prize for innovation in 2014 (Catalan News Agency, 2014). Currently, the city is developing a Smart City campus in the 22@ technology district, which is due for completion in 2025 (22@ Barcelona, n.d).

In 2022, the city serves as a highly productive hub for start-ups. Here is a summary of its accomplishments:

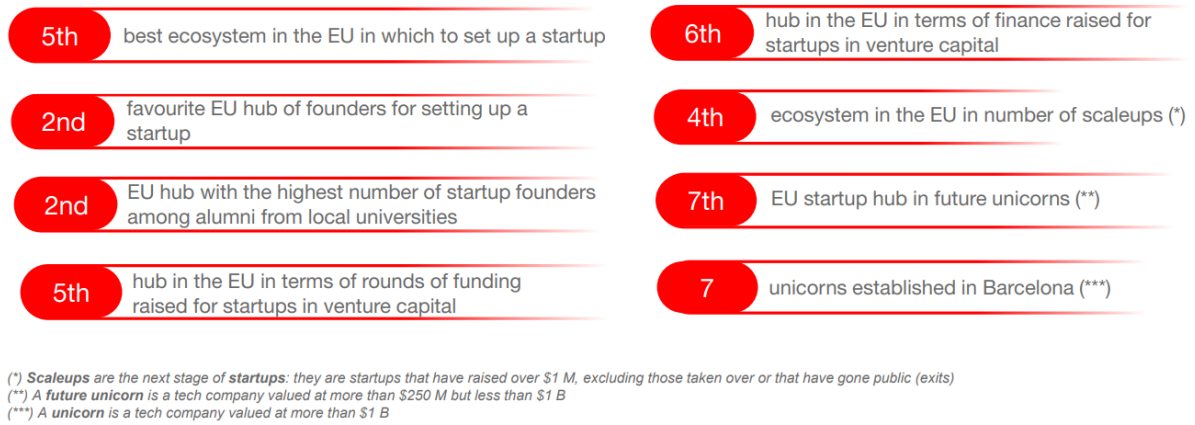

Figure 4.1: Barcelona start-up system performance overview, Source: (ACCIÓ Regional Government of Catalonia 2023).

Barcelona has been ranked as the fifth-best startup ecosystem in the European Union, surpassed solely by Paris, Berlin, Stockholm and Amsterdam. In 2022, Catalonia saw a record-breaking investment of €1,653 million in startups, which is an increase of 4.3% from the previous year. Over the prior five years, Catalan startups secured a cumulative investment of €5,043 million, indicating the ever-increasing robustness of the entrepreneurial ecosystem.

76% of these firms' priorities technologies related to Industry 4.0, emphasizing the significance of digitization and technological conversion in the manufacturing ecosystem of Catalonia.

Additionally, 79% of startups in Catalonia allocate funds to Research and Development (R&D), with 48% of them dedicating over a quarter of their income to said purpose and 30% investing more than 50%. Half of these start-ups (49%) are covered by a patent or knowledge protection system (Startups in Catalonia - catalonia.com, n.d.).

This illustration offers a concise overview of economic diversification in Catalonia's entrepreneurial ecosystem, emphasizing the key sectors that start-ups operate within:

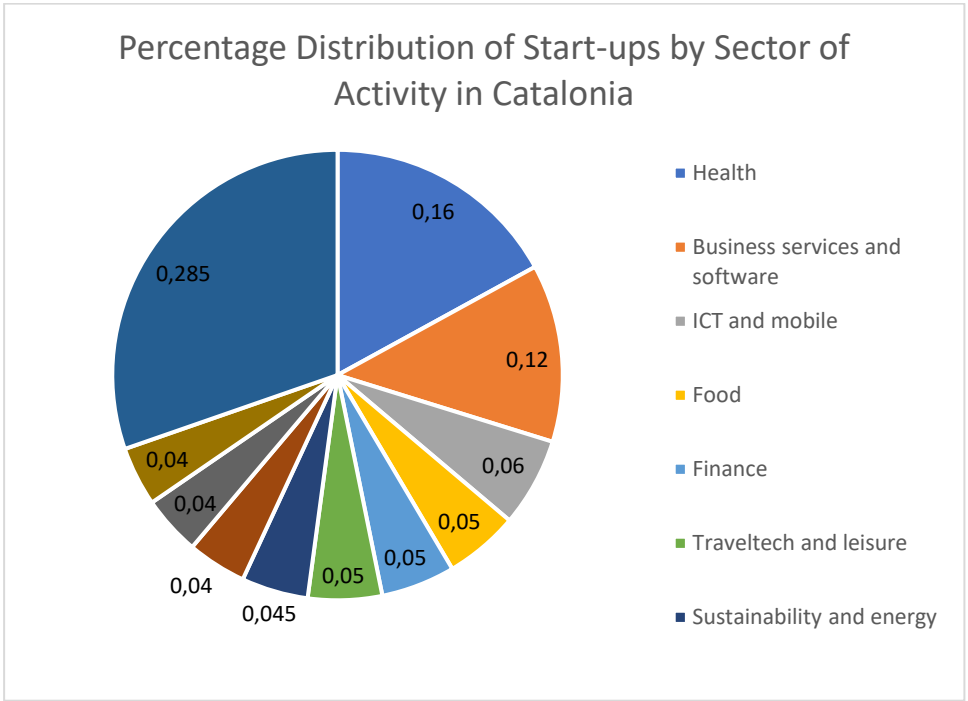

Figure 4.2: Percentage Distribution of Start-ups by Sector of Activity in Catalonia, Source: (*Startups in Catalonia - catalonia.com*, n.d.)

The diagram illustrates a cake composed of different colored slices, each of which corresponds to a distinct sector where Catalan start-ups are presently engaged. Notable sectors consist of healthcare, representing 16% of the aggregate, business services and software (12%), information and communication technology and mobile (6%), food (5%), and finance (5%). In addition, emerging sectors include traveltech and leisure (5%), sustainability and energy (4.5%), e-commerce and marketplaces (4%), digital content (4%), and education technology (4%). The category "Other" represents 28.5% of the total and includes several unspecified sectors (Startups in Catalonia - catalonia.com, n.d.).

Barcelona is renowned for its dedication to sustainable urban innovation, forming alliances with start-ups and companies through initiatives like DataCity (ITU/UN tech agency, 2021).

The city values public-private partnerships, responsible public procurement, and entrepreneurship as critical elements (Barcelona City Council, 2021).

As Barcelona asserts, it has a high Total Entrepreneurial Activity, acknowledged not only in Spain but also in Europe (Call for Paper | GEM Acede 2023, n.d.), as evidenced by several studies conducted in Spain (De Barcelona, n.d.) and Europe. This demonstrates strong economic sustainability and aligns with the city's objectives for the 2030 Agenda.

To attain its operational goal, the city strives to maintain a TEA rate of over 10% among individuals aged 18-64. The most recently available statistic from 2018 is 8.6 (Barcelona City Council 2020).

Barcelona Activa, a municipal entity managed by Barcelona City Council, plays a vital part in promoting entrepreneurship in the city. It provides diverse venues and resources fashioned to bolster entrepreneurs. Some of these locations include Glòries, Almogàvers, Media TIC, ESA BIC, the Technology Park, and InnoBadora. These facilities act as incubators for innovative start-ups and provide a favorable environment for entrepreneurial initiatives.

The private sector in Barcelona has contributed significantly to the development of a technology entrepreneurial ecosystem. Notable examples include Pier 01 and Pier 02, which have become hubs for technological innovation and the growth of start-ups. One such successful start-up is Glovo, an on-demand delivery platform that has achieved global success. Additionally, the existence of Business Angels in the city's entrepreneurial landscape suggests a robust network of private investors keen to back innovative ventures.

Furthermore, the city is placed 50th in the Top 100 S&T clusters for patent sharing and 65th in the Ranking of S&T intensity, 2016-2020, according to the World Intellectual Property Organization (WIPO) in 2022. The city's global rankings for patents and scientific publications show a sharing of 0.14% of S&T per capita. Barcelona has been awarded the European Entrepreneurial Region Award 2023 for successfully integrating its entrepreneurship strategy into the 'Barcelona Green Deal' urban and economic agenda (Ajuntamento de Barcelona, 2022).

The Barcelona City Council's Agenda 2030 advocates for responsible public procurement, public-private partnerships, and entrepreneurship to support social justice and environmental sustainability (Barcelona City Council, 2021).

Barcelona's smart city initiatives have attracted an investment of more than €4 billion, leading to the creation of new jobs and stimulating economic growth (Morningstar, 2023). These efforts received support from various targeted policies and programs aimed at bolstering the city's productivity and economic resilience. Let us delve into the focus areas in more detail:

Tax Exemptions and Rent Relief: The 'Amunt Persianes!' program has reserved £17 million for the local economy. These funds will be used to provide tax exemptions and rent concessions, essential measures to support local economic activities and enhance productivity.

Promoting economic efficiency and innovation, initiatives such as the 'BCN Retail Lab' and targeted investments in digitization are being implemented. A significant £100 million investment has been

allocated for market restructuring, minor projects, and digitization, making a noteworthy contribution to the goal of enhancing economic competitiveness.

Governance of the Economy: The creation of CECORE, an interdepartmental management team responsible for continuous monitoring of the economic situation, and the endorsement of the 'Agreement for the Revitalization of Barcelona', emphasize the local government's prioritization of the city's economy. This demonstrates a firm commitment to sustainable economic growth.

Economic diversification: The 'Barcelona Green Deal' outlines a strategic roadmap for economic diversification that seeks to create high-quality jobs in the digital and environmental sectors. This diversification will enhance the resilience and adaptability of Barcelona's economy to future challenges.

Startup Incentives: Supporting startups is a clear priority, as demonstrated by the implementation of innovation spaces and partnerships with key organizations such as Correos. These initiatives promote innovation and economic growth by supporting the entrepreneurial ecosystem.

the Social and Solidarity Economy (SSE): is highly valued. SSE and the collaborative economy form fundamental components of Barcelona's economic model and have proven valuable during periods of rapid change, such as that caused by the pandemic. Programs like 'MatchImpulsa' provide financial support to collaborations between technology firms and SSE entities, promoting a more inclusive and equitable economy (Barcelona City Council, 2020).

To assess the effectiveness of the economic measures, we will consider two key indicators: the growth rate of Gross Domestic Product (GDP) and the unemployment rate. These indicators offer an overview of the city's economic performance during the relevant period.

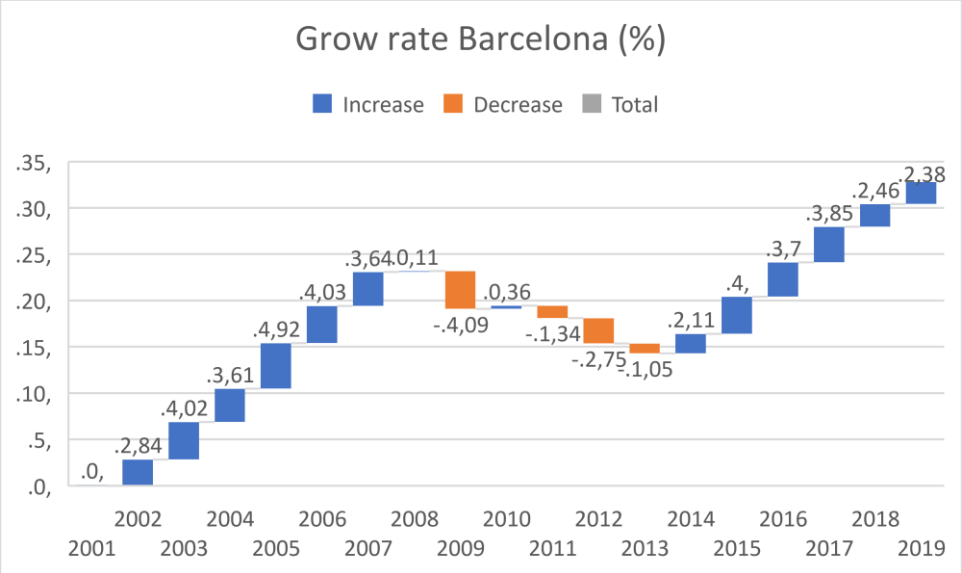

Figure 4.3: Barcelona GDP Growth Rate (2001-2019), Source: (OECD, n.d.)

During the period 2001-2007, Barcelona underwent steady economic development, with GDP growth rates ranging from 3.61% to 4.92%. This was a time of resilient economic expansion that saw the city benefit from rising investments and tourist inflows.

However, in 2008-2009, during the 2008 Crisis, Barcelona faced a significant decline of -4.09% owing to the global effects of the financial crisis. This proved to be an economic hurdle with a steep reduction in activity.

After the crisis, Barcelona exhibited a gradual yet consistent recovery from 2010 to 2014, showing initial negative GDP growth rates but ultimately reaching significant growth of 2.11% in 2014.

From 2015 to 2019, the city demonstrated relatively stable economic growth, with GDP growth rates fluctuating between 2.38% and 4.7%. This could indicate the efficacy of economic policies and investments made in technological innovation as introduced through the 2011 IT strategy.

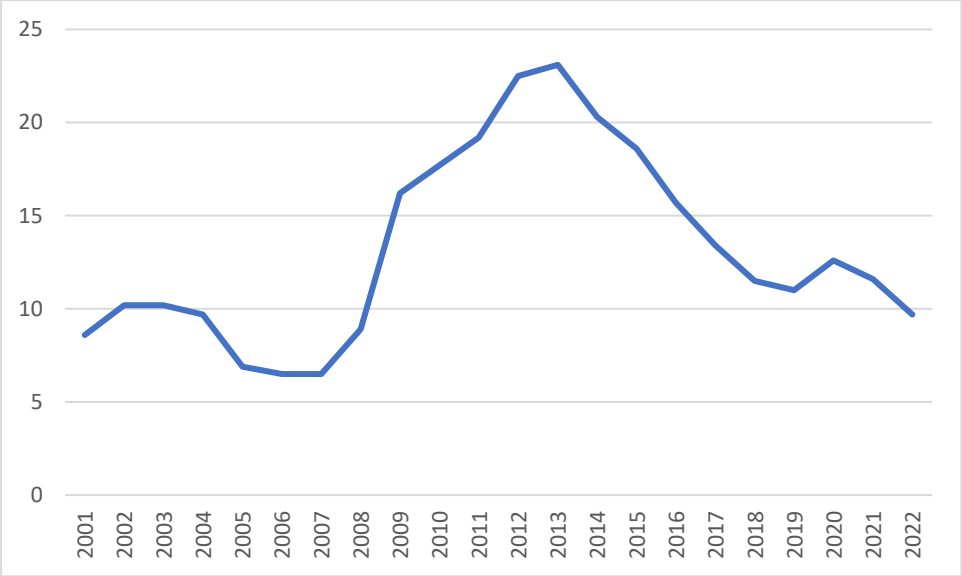

Figure 4.4: Barcelona Unemployment Rate % (2001-2022), Source:(Idescat. n.d.)

In relation to employment, Barcelona has undergone varying phases throughout the years.

From 2001 to 2007, the unemployment rate began at 8.6% and decreased to 6.5% in 2007, indicating a stretch of economic stability prior to the 2008 Global Financial Crisis.

During the Crisis of 2008, specifically in 2008-2009, the unemployment rate spiked to a notable 8.9%, reflecting the impacts experienced due to the global financial crisis that struck the city.

The crisis exerted a negative influence on employment throughout 2009-2010. The unemployment rate reached 16.2% in 2009 and further rose to 17.7% the succeeding year.

Despite the increase to 19.2% in the subsequent year, a digital transformation IT strategy was unveiled, revealing the authorities' intent to enhance the economy's effectiveness and encourage growth in the long term.

Over the 2014-2019 period, the unemployment rate saw a gradual decline, falling to 11% in 2019.

From 2014 to 2019, there was a gradual reduction in the unemployment rate, which reached 11%. This decrease in the unemployment rate indicates a continued economic recovery.

The global economy was affected by the COVID-19 pandemic from 2020 to 2022, resulting in an increase in the unemployment rate to 12.6% in 2020. Nevertheless, the rate subsequently decreased to 11.6% and 9.7% in 2021 and 2022, respectively.

More than half of the jobs in Barcelona (56.9%) belong to the knowledge-based sector, of which 42.8% are knowledge-intensive, confirming its status as a technology and innovation hub.

The labor market in Barcelona is distinguished by a notable presence in high value-added sectors, with a considerable number in technology-intensive sectors and knowledge-intensive high-tech services (Ajuntamento de Barcelona, 2022).

Barcelona is ranked 26th in the Global City Index (A. Kearney, Inc 2022) and serves as an exemplary model of how cities can promote sustainable development by balancing their global and local interconnectedness.

Goal 17.2 targets the allocation of 0.7 percent of the municipality's resources to international cooperation projects by 2030. The available data through 2019 indicates a figure of 0.63 percent (Barcelona City Council 2020).

Important to the reports is the "Barcelona Plan, Global City: Master Plan for International Relations 2020-2023," which was updated in 2023/2026 (Plan Director De Cooperación Para La Justicia Global 2023-2026 | Barcelona Ciutat Global, n.d.; Barcelona City Council, 2021). The plan endeavors to endorse international collaboration and integrate the 2030 Agenda. In addition, the city is actively involved in various global programs such as the C40 network on climate justice and "Cities Race to Zero," along with initiatives connected to climate change and digital transformation (eurocities, Cities for Digital Rights), and holing technology conferences.

Of paramount importance is the dedication to fostering horizontal employment, evidenced by the sanctioning of 57 collaboration schemes in 2020, of which 13 were executed in tandem with accords made with priority cities for the municipality. Furthermore, the city is crafting a Global Justice Education Strategy and advancing in the execution of the 2030 Agenda at the local level (Barcelona City Council, 2021).

In addition, the interview with Bria, upon his appointment as Commissioner of Technology and Digital Innovation for Barcelona City Council, sheds light on the city's plans to spearhead a public project aimed at transforming the city digitally. According to the interview, the city aims to develop an open digital marketplace that promotes transparency in procurement processes and facilitates fair competition for small businesses in relation to large ones. This approach is based on the concept of treating data as a public asset and a shared resource, thereby contributing to the development of a regional innovation ecosystem (ITU/UN tech agency, 2021).

The statistic that almost a quarter of workers in Catalan startups (23%) are foreign, and 19% of startup founders come from other countries, indicates the diversity and international attractiveness of the startup sector in Catalonia.

Furthermore, directing attention towards fields with a high number of foreign professionals - such as technology, sales, and strategic management - emphasizes the significance of global knowledge for achieving startup success.

Information from ACCIÓ - Catalonia Trade & Investment shows that 67% of Catalan startups have foreign clients, contributing 44% of their average revenue. This demonstrates the ability of startups to effectively compete globally and create value through international partnerships.

Barcelona is a significant center for foreign investment, as indicated by its numerous prominent positions in international rankings.

Ninth place worldwide was achieved in terms of attracting foreign investment projects in 2020.

Second place was secured for research center projects based on KPMG's Global Cities Investment Monitor report for 2021.

In addition, it ranked seventh in Europe as a promising city for tech startups, and fifth for foreign direct investment (FDI) projects in the technology sector, according to fDi Intelligence's 2021 report.

According to the EY Attractiveness Survey Europe, Barcelona ranks 10th in terms of international investment appeal.

Barcelona also earned recognition as the European city with the best approach to attracting foreign investment, as highlighted in FDi Intelligence's European Cities and Regions of the Future 2022/23 report. Additionally, the city ranks ninth in terms of attractiveness for foreign workers and tenth for digital experts (Ajuntamento de Barcelona 2022). Regarding foreign investment, which is affirmed by prominent rankings on an international level.

4.1.2 Technology

The role of technology in the urban transformation of Barcelona is a critical aspect to consider. This analysis, based on data collected from interviews with experts, including the Head of Technology and Digital Rights at the City of Barcelona's Commission for Digital Innovation (source: [Interview] Barcelona Moves to Humanise Technology | UserCentresCities, n.d.), as well as voluntary indices and reports, will scrutinise how the integration of technological systems affects the city's development.

Barcelona ranks 29th in the Global City Outlook (A. T. Kearney, Inc., 2022), foretelling a future of worldwide challenges and possibilities. This standing is not solely due to economic expansion, but also to the strategic implementation of innovative technologies that enhance the citizens' quality of life and the management of urban resources.

This analysis will enable a more comprehensive comprehension of how Barcelona can succeed in the digital age by taking advantage of emerging opportunities and averting the challenges associated with the rising implementation of technology.

Barcelona excels in several security categories based on the Safe Cities Index 2021 report. Its impressive score of 72.9 in Digital Security is a testament to the city's robust digital security infrastructure and safeguarding of sensitive data.

Another noteworthy achievement is seen in Health Security, with a score of 78.1, indicating that Barcelona has successfully implemented measures to guarantee the health security of its inhabitants. This is specifically significant given the increasing importance of digital health.

Lastly, Barcelona also surpasses expectations in Infrastructure Security, scoring 83.7, indicating a considerable investment in safeguarding the city's infrastructure. This contributes to the urban resilience of the city, a crucial aspect in emergencies and external threats management (Safe Cities Index 2021, n.d.).

Barcelona is adopting a proactive stance in employing technology for security enhancement. The city is displaying its dedication to embracing emerging technologies with the implementation of innovative initiatives such as wearable cameras, gunshot detection systems, and real-time crime mapping (Statista, 2022).

Furthermore, Barcelona is using 5G technology to develop pioneering solutions in different areas, comprising education, industry, commerce, tourism, transport, and emergency management, in preparation for the future (Statista, 2022).

Additionally, the city has established tele-assistance services and a city operating system to boost the citizens' quality of life and streamline urban management. Initiatives like smart traffic lights and traffic light control in emergencies showcase Barcelona's proactive approach to urban safety (BCN Smart City, 2016).

Finally, Barcelona is investigating personal data protection using blockchain technology, acknowledging the potential competitive benefits this technology could provide, particularly in relation to the EU's General Data Protection Regulation (GDPR) (ITU/UN tech agency, 2021).

In summary, Barcelona is making noteworthy headway in enhancing its security across multiple domains. Such advances highlight the city's long-term objective to ensure greater safety.

Barcelona, a culturally rich and historic city, has utilized digitization to enhance its cultural scene and events. Notably, festivals such as Sonar and Primavera Sound have acted as catalysts for growth, creating opportunities that result in an annual economic impact of around £4,500 million (Ajuntament Barcelona, 2020).

The Smart City Expo World Congress held in November 2019 highlighted the significance of technology in organizing events of international importance, bringing together professionals, mayors, and multinational firms with a considerable financial influence (Ajuntament Barcelona, 2020). Additionally, Barcelona is the birthplace of the Mobile World Congress (MWC), the primary trade fair for mobile platforms worldwide. Although cancelled in 2020 due to the COVID-19 pandemic and postponed until

June and July 2021, the event continued to make a significant contribution to the city's economy, attracting thousands of global companies and visitors (HEC Paris, 2021).

The city has shown competence in incorporating technology into cultural events, as demonstrated by the '48h Open House BCN'. This event incorporates cultural features that are enhanced by technology to enrich the experience of visitors (Barcelona - Open House Worldwide, n.d.). In addition, the city has implemented various initiatives pertaining to education and culture, including mSchools, Smart Allotment and Infantium, which utilize cutting-edge technologies to enhance education and cultural experiences throughout the city.

Moreover, digitization has been embraced by Barcelona's museums, as they have introduced digital endeavors like virtual tours and social media contests (Ajuntament Barcelona, 2020). A survey conducted by the Institute of Culture in Barcelona has yielded significant information on the alignment of cultural offerings with the requirements of locals and visitors, as well as drawn attention.

However, the citizens of Barcelona highly value culture, regardless of their residence, gender, ethnicity or nationality, underscoring its central role in the city's life (Ajuntament Barcelona, 2020). In addition, initiatives like the Adolescence and Youth Plan (AYP) have engaged numerous young individuals, encouraging their involvement in cultural activities and local community engagement.

Barcelona has provided training programs for parents and offered discounts on cultural event tickets to facilitate young people's attendance. Such youth orientation and training programs, inclusive of those related to sports and school orientation, highlight the city's commitment to ensuring broad youth participation in cultural events (HEC Paris, 2021). The city's cultural life has been further enriched by digitalization, creating more accessible and inclusive events for all residents.

Barcelona is implementing various initiatives aimed at promoting social inclusion, including the use of digital technology to enhance citizens' lives. An instance of such an initiative is the Vincles BCN project, which seeks to combat isolation among the elderly and individuals with limitations through social support provided by technological devices. Additionally, Barcelona is striving to enhance accessibility to digital services for everyone while promoting "intellectual ergonomics" to enhance service comprehensibility (UserCentresCities).

The city's priority is to include people with disabilities. It aims to ensure that 9% of the population with disabilities has access to personal autonomy and independent living programs. Additionally, the city has established an office specifically for handling discrimination complaints and is committed to combating discrimination based on several factors.

The city is endeavoring to advance the incorporation of individuals with disabilities, who form 9% of the entire population. The declared objective is to increase by twofold the quantity of individuals with disabilities and functional diversity gaining access to programs facilitating personal autonomy and independent living.

The city is committed to combating discrimination based on various factors, including ideology, gender, social class, origin, sexual orientation, language, and religion. A specific office has been established to handle complaints of discrimination.

Additionally, it aims to reduce the AROPE rate, an indicator of the risk of poverty or social exclusion, is a crucial point of focus. The rate was 23.1% in 2016-2017 which is above the target of 15% set for 2030, highlighting the need for further efforts to address social inequalities.

The prevalence of loneliness among adults, which stands at 8.8%, is a key area of focus. The goal is to lower this percentage, along with the AROPE rate, to below 6%, demonstrating Barcelona's commitment to the emotional well-being of its residents.

The Barcelona City Council's global goals involve advancing social, economic and political integration for all, with the intention of decreasing the likelihood of poverty or exclusion to less than 15%, showcasing Barcelona's aspiration for a fairer and more all-encompassing society. Barcelona City Council, 2020).

Additionally, there is a dedication to fostering inclusivity and diversity for young adults, considering that 42% of them were born outside of the country, Programs like the BCN Interculturality Program

engage about 2,500 young individuals and approximately 9% of 18–34-year-olds are part of local associations that encourage inclusion (Barcelona City Council, 2020; HEC Paris, 2021).

Smart Living Barcelona initiatives are revolutionizing the health and social services sector in the Catalan city. Programs such as Telecare and Vincles BCN provide remote support to elderly or disabled people by using alarms, sensors, and innovative technologies, guaranteeing them a constant and safe level of care. Telecare represents a significant breakthrough in this field. In 2014, Vincles BCN achieved international acclaim by triumphing in the Bloomberg Philanthropy competition, which aims to acknowledge the most inventive projects dedicated to enhancing citizens' wellbeing. This initiative provides crucial assistance to senior citizens, facilitating the prevention of social exclusion through support rendered by digital devices such as tablets or smartphones.

Furthermore, Barcelona has adopted the smart city concept by employing sophisticated digitization strategies, including the utilization of big data analytics, to enhance healthcare. The integration of big data into healthcare holds great potential to boost the efficiency of healthcare services, elevate the standard of patient care, and enhance the effective use of the available resources. Through the incorporation of advanced technologies and data analysis, Barcelona aims to accomplish critical goals, including sustainability, resilience, and intelligent management of healthcare resources. Such goals align with the objectives delineated by Mohamed and Al-Jaroodi in 2015.

A primary objective is SDG 3 of the UN, which advocates health and well-being. The aim is to enhance the health of mothers, newborns and the population at large by providing access to superior health facilities. Barcelona has achieved substantial advancement towards this aim by reducing maternal and infant mortality, with ambitious goals for the future. Maternal mortality is projected to be lower than 0.1 per 1,000 live births, and neonatal mortality is anticipated to be less than 1 per 1,000 live births by 2030.

The city is also taking measures to prevent the transmission of sexually transmitted infections like gonorrhea, with the goal of decreasing the prevalence to fewer than 200 cases per 100,000 individuals for men and below 20 cases per 100,000 individuals for women by 2030. In addition, active efforts are being made to lower the rate of premature mortality among children under five to below 35 per 100,000 and neonatal mortality to below 1 per 1,000 by 2030.

Technology is crucial to the implementation of these ambitious health strategies. Sources such as mortality registers, health surveys, and epidemiological data facilitate access to crucial health information. Technology is utilized to gather, analyze and disseminate health information, such as records of sexually transmitted diseases and COVID-19 data. This technologically driven approach is essential for identifying health challenges, devising responses to emergencies, as seen during the COVID-19 pandemic, and continuously monitoring progress towards health objectives.

In addition, Barcelona is devising a dedicated emergency preparedness plan to address outbreak situations. This plan involves the procurement of necessary health materials and the provision of extra health resources. Such steps demonstrate the city's steadfast commitment to always safeguarding the health and welfare of its residents (Barcelona City Council, 2020).

The matter of data transparency and citizen involvement is a pivotal aspect of smart city management. In Barcelona's case, the city has implemented an "experimental and democratic" model for its smart city, giving significant importance to digital law and ethics (HEC Paris, 2021). The city, under the guidance of individuals such as Bria, who possess extensive knowledge in innovative economics, has created approaches that rely on open data. The digital platform Decidim. Barcelona is an exemplary instance of how technology can promote active citizen participation in decision-making (Interview | UserCentresCities, n.d.).

The city has also initiated programs like DECODE, in association with 14 other European cities, to revive electronic democracy (ITU/UN tech agency, 2021). These initiatives and platforms strive to prioritize the user in all actions, while strengthening their digital sovereignty and protecting their data privacy and rights.

Barcelona currently boasts an Open Data portal containing over 597 reusable datasets (Datasets - Open Data Barcelona, n.d.).

The pie chart presented here aims to provide a clear and immediate view of the distribution of the datasets available in the Barcelona Open Data portal, broken down by sector of interest. The sectors considered are: Administration, City and Services, Economy and Business, Population and Territory. The objective is to provide an overview that helps understand where the city is focusing its efforts in terms of open data collection and dissemination:

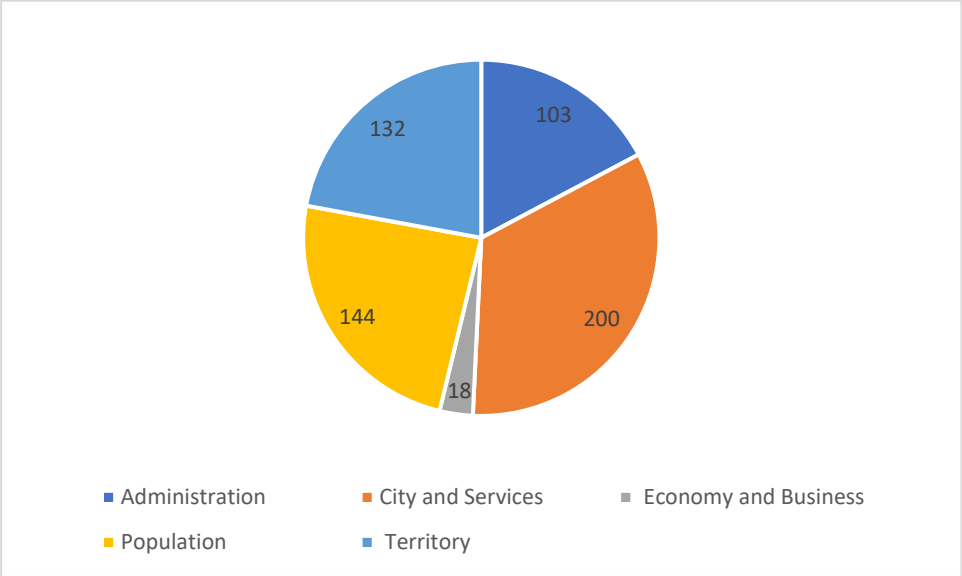

Figure 4.5: Distribution of Available Open Data Sets by Sector in Barcelona, Source: (*Datasets - Open Data Barcelona*, n.d.).

The pie chart shows a strong concentration of datasets in the 'City and Services' sector, with 200 datasets, which represents the core of Barcelona's smart city initiatives. This is followed by the 'Population' and 'Territory' sectors, with 144 and 132 datasets respectively, indicating an interest in demographic and geospatial data.

The category 'Administration' contains 103 datasets, signaling a commitment to administrative transparency and governance. In contrast, 'Economy and Business' appears less represented with only 18 datasets, suggesting that it may be an area in need of further development.

The distribution of datasets highlights the city's current priorities in terms of open data and provides insights into where further data collection might be needed to balance the city's information ecosystem.

This information ecosystem provides a trusted environment in an era of digital disinformation and allows for monitoring efforts to address the digital divide (Digital Future Society, n.d.). At the same time, the city is working to reduce the digital divide and compensate for inequalities through educational programs (HEC Paris, 2021).

The case of Barcelona can serve as a model for other cities in terms of how to manage technology and data in a democratic and transparent way. However, there is an urgent need to develop new agreed indicators for digital inclusion and to update approaches to digital literacy to make digital technologies more inclusive tools for citizen empowerment (Digital Future Society, n.d.).

Barcelona is a city where sustainable mobility is a clearly defined priority and implemented through several initiatives. A focal point is the concept of "superisolates," which aims to redesign urban architecture to prioritize non-motorized forms of mobility such as walking and cycling. Superisolates

not only encourage pedestrian mobility through reduced speed limits of 30 km/h and pedestrian friendly crossings, but also promote a participatory urban environment. They allow, for example, a greater degree of autonomy for children on their way to school, developing a sense of social responsibility within communities (HEC Paris, 2021).

Barcelona's cycling initiatives are also noteworthy. According to data, 72 percent of the city was covered by a network of bike lanes in 2017, with a target of 95 percent coverage. These measures, along with accident and safety monitoring programs, have made cycling an increasingly popular and safe mobility choice (Ajuntament de Barcelona, 2022). The expansion of the city's bike lanes has been impressive, growing from 128 km added in 2012 to 240 km in 2021. At the same time, the city's bike-sharing service, Biking, reached more than 130,000 users in 2021, suggesting a growing social acceptance of bicycles as a means of transportation (Ajuntament de Barcelona, 2022; Barcelona Urban Mobility Index City Data - HERE, n.d.).

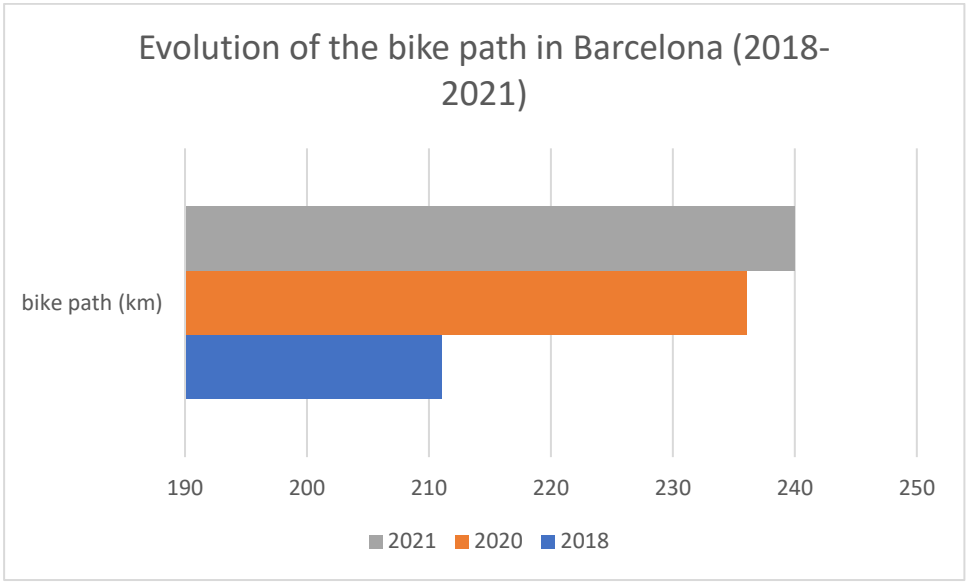

Figure 4.6a: Evolution of the bike path in Barcelona (2018-2021), Source: (Ajuntamento de Barcelona, 2022)

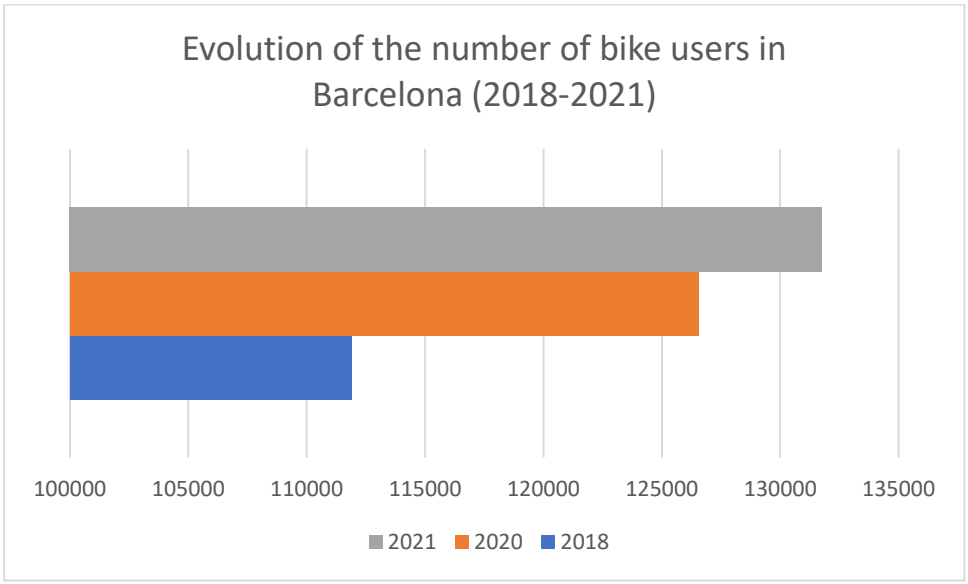

Figure 4.6b: Evolution of the users in Barcelona (2018-2021), Source: (Ajuntamento de Barcelona, 2022)

The graph shows an increasing trend in both the construction of bike lanes and the use of the Biking service. This suggests not only that the city is investing in infrastructure to facilitate non-motorized mobility, but also that there is growing interest and adoption by the population. This data underscores Barcelona's success in promoting cleaner and more sustainable forms of mobility.

Despite these measures, there are opportunities for further improvement. For example, Barcelona ranks 17th globally for sustainable mobility, with 85 percent of all internal trips made sustainably (Ajuntamento de Barcelona, 2022). The strategy to promote clean, non-motorized mobility is well aligned with the city's broader sustainability goals, but ongoing evaluation is needed to address emerging challenges and further improve its efficiency (Ajuntamento de Barcelona, 2020).

Barcelona presents itself as a dynamic site for developing pioneering ICT (Information and Communication Technology) solutions, with projects ranging from data handling to eco-friendly transportation (Ajuntament de Barcelona, 2016g; Statista Search Department, 2022; Barcelona city council, 2022). The Catalan Centre for Transport Innovation (CENIT) conducts research in demand analysis and transport policy to mitigate traffic congestion and improve mobility (Cenit, 2023; Smartcities worldprofiles, 2019).

A key initiative is "Sentilo," a sensory platform that integrates real-time data from a network of distributed sensors to optimize public services (Statista Search Department, 2022). This sensor network is integrated within a three-tier IT architecture: Information Sources layer, Middleware layer, and Smart Applications layer. Similar ICT applications have extended to the "Orthogonal bus" project, which employs analytical data to optimize the public transport system, incorporating buses, trams, and underground trains (Barcelona city council, 2022; Velazquez-Romera, G., 2017).

The city is at the forefront of public connectivity with Barcelona investing in 590 Wi-Fi points and Internet of Things (IoT) solutions to enhance interconnectivity. Cisco predicts that these investments will generate cumulative economic benefits of 747 millions of euros by 2026.

Nevertheless, there are challenges to overcome, such as effectively using collected data for sustainable decision-making (Bibri & Krogstie, 2020). In addition, the presence of private transport services such as Uber and Cabify has posed difficulties, requiring a reassessment of strategies.

The facilitating of an inclusive digital transition among citizens is deemed a key lever in the promotion of technology education. Municipal policies that prioritize the use of technology and creativity in classrooms to encourage scientific literacy and technological occupations are also beneficial in this regard (HEC Paris, 2021).

Nevertheless, Barcelona surpasses basic technologization, focusing instead on the individual's significance, which is deemed more crucial than the mere adoption of cutting-edge technologies. This comprehensive approach ensures that technologies function as instruments to identify areas for improvement, facilitate decision-making processes, and enhance inclusivity in the labor market, mitigating the digital divide and compensating for economic and educational disparities.

From a political perspective, the Neighborhood Plan 2021-2024, with a budget of €150 million, foresees the activation of new public policies and the involvement of citizens in urban regeneration projects (Barcelona City Council, 2020). The core creative industry in the city generates a turnover of over £10 billion, establishing Barcelona as one of the most creative cities in Europe, according to the Cultural and Creative Cities Monitor Report 2019 (Ajuntamento de Barcelona, 2022).

Digital education is a vital topic for sustainable urban development and Smart Cities, particularly in the context of Barcelona and Singapore. A multi-faceted approach to education is recommended in Barcelona, with universities encouraged to incorporate subjects such as Big Data, sustainability, and ethics into their curricula to provide a comprehensive education (Grimaldi & Fernandez, 2017). This is supported by the evidence that Barcelona possesses exceptional educational establishments, including IESE and ESADE, which are ranked in the top 10 business schools in Europe (Ajuntament de Barcelona, 2022).

The Catalan city has already implemented initiatives such as mSchools and Smart Allotment to enhance education using advanced technologies (Citizen Empowerment and Inclusion | Digital Future Society, n.d.). There is also an emphasis on interdisciplinary collaboration among academic departments like Physics, Mathematics, and Business Administration in the development of a Smart City.

Demographically, the Barcelona Metropolitan Area hosts 82% of Catalonia's university students, over 55,000 of whom are enrolled in master's and doctoral programs in the 2020-2021 academic year (Ajuntament de Barcelona, 2022). This shows a significant concentration of expertise and a clear inclination towards higher education, which could be further enhanced through better integration of digital education.

In operational terms, the Barcelona City Council aspires to decrease education segregation and guarantee impartial usage of digital and online learning for each student (Barcelona City Council, 2020). Additionally, it strives to increase levels of upper secondary education and language proficiency, as well as promote awareness concerning issues like sustainable development and human rights.

In the realm of smart tourism, Barcelona stands out as a landmark for its adeptness at incorporating digital technologies into tourism and hospitality strategies. Between 2014 and 2019, this city generated 20% of Catalonia's jobs in the tourism sector, amounting to approximately 410,000 positions (HEC Paris, 2021). Nevertheless, this expansion has given rise to social and political pressures. For instance, there have been protests the existence of Airbnb, which runs approximately 16,000 holiday rentals in the city, almost 7,000 of which are not licensed (Burgen, 2020).

On the regulatory front, the city has taken rigorous actions, such as levying a fine of €600,000 on Airbnb and doubling the number of inspectors from 20 to 40 (HEC Paris, 2021). These regulatory endeavors coincide with a 23% rise in rents during the past three years and pressure on certain popular areas, where people pay up to 60% of their income in rent.

Notwithstanding the difficulties, the city has received commendations for its sustainable tourism management and attained Biosphere Platinum certification in 2022. It has also created intelligent tourism programs utilizing IoT technology to deliver current information and individualized suggestions via a mobile application (Morningstar, 2023).

Infrastructure-wise, Barcelona is easily accessible, boasting an international airport, a port, an exhibition center, and a free zone, all within a 5-kilometre radius. In 2021, El Prat Airport saw a 48.2% increase in passenger traffic, with 18.8 million passengers passing through (Ajuntament de Barcelona, 2022).

Regarding public perception, a 2019 survey found that 72.9 percent of residents see tourism as beneficial, while only 16.6 percent see it as harmful.

This paper examines the temporal evolution of three key indicators related to tourism in Barcelona. The indicators in question are average spending per tourist accommodation (Indicator 893A), average spending per tourist per day (Indicator 893B), and the ratio of tourist accommodation to resident population (Indicator 894). Using data collected in the years 2015-2020, this study aims to provide a comprehensive picture of trends in these areas and compare them with the projected targets for 2030

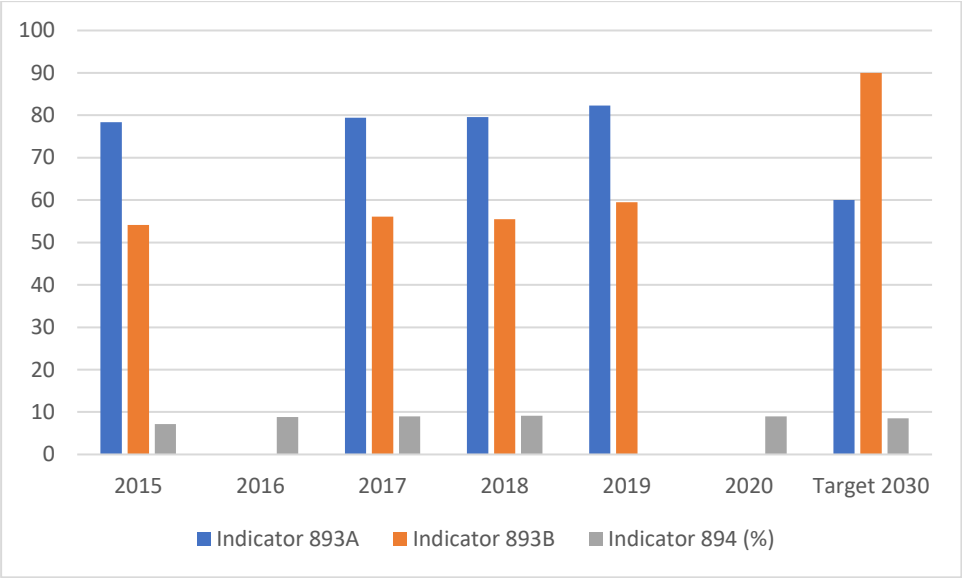

Figure 4.7: Analysis of Barcelona's tourism indicator 893A, 893B, 894, Source:(Barcelona City Council, 2020; Barcelona City Council, 2021).

The line graph shows a general upward trend for Indicators 893A and 893B, with peaks in 2019. However, Indicator 894 shows a slight fluctuation, exceeding the target of 8.5 percent in 2016, then stabilizing around 9 percent in the following two years. A decline is also noted in 2020, likely due to travel restrictions related to the COVID-19 pandemic.

While Indicators 893A and 893B appear to be progressing toward their respective targets, Indicator 894 has already exceeded its intended target, raising questions about the balance between tourism and residents. These data suggest the need for targeted strategies to balance tourism development and local people's well-being.

4.1.3 Sustainability

In the search for sustainable urban models, Barcelona is a quintessential case study. Beginning in the 1980s, the city underwent a transformation with the aim of becoming a paragon of sustainability and innovation (Barcelona Smart City, 2014, p. 10). The transformation is characterized by three strategic pillars: intelligent waste management, water optimization, and energy preservation, all of which aim to achieve self-sufficiency with zero-emissions.

In 2012, Barcelona commenced its Smart City program with a goal to develop into a global innovation center. The program prioritized environmental efficiency, as well as quality of life and social equity (HEC Paris, 2021). One of its pioneering initiatives is the 'superblocks' project, which aims to enhance urban infrastructure through eco-friendly and interconnected design.

In accordance with the recommendations of the European Commission, the city has implemented cutting-edge solutions, including intelligent transport networks and energy-efficient constructions. An outstanding illustration is the intelligent lighting system, which has achieved a 30% reduction in energy usage, resulting in savings of over €36 million (Morningstar, 2023).

This chapter will analyze the innovative mechanisms adopted by Barcelona to contribute to the UN's Sustainable Development Goals. It will specifically examine how these initiatives fit into a global context of sustainability.

The redevelopment of the previous Sant Martí Ca l'Alier factory into a zero-emission center serves as a prime example of sustainable construction in Barcelona. The project retains the factory's original architectural design while incorporating noteworthy advancements resulting in a cutting-edge, environmentally friendly, and energy-efficient structure (Rodríguez, 2014). This transformation plays

an essential role in a city where government-owned buildings and amenities contribute nearly 50% of the city's total energy consumption.

Expenditure on Sustainable Development Goal 7 by the municipality amounts to £13.3 million, which is 0.60% of the total budget. Simultaneously, over £21 million has been reserved for enhancing housing quality, with 84% of the funding aimed at renovation (HEC Paris, 2021; Barcelona City Council, 2021). These efforts primarily focus on energy efficiency, with new construction models such as passive and zero-energy houses receiving more attention.

The local government is collaborating with private enterprises to establish a sustainable housing inventory. They are currently renovating 34,000 square meters of residential space. Buildings, like Diagonal 640, have acquired LEED certification, demonstrating the significance of efficient water and energy usage, and ethical waste disposal. (Glasco, 2019).

This chart presents a comprehensive synopsis of the income and spending breakdowns in municipalities. Its purpose is to establish the allocation of funds on sustainable infrastructure, such as Passive Houses, within the framework of a local government that offers a range of services and duties.

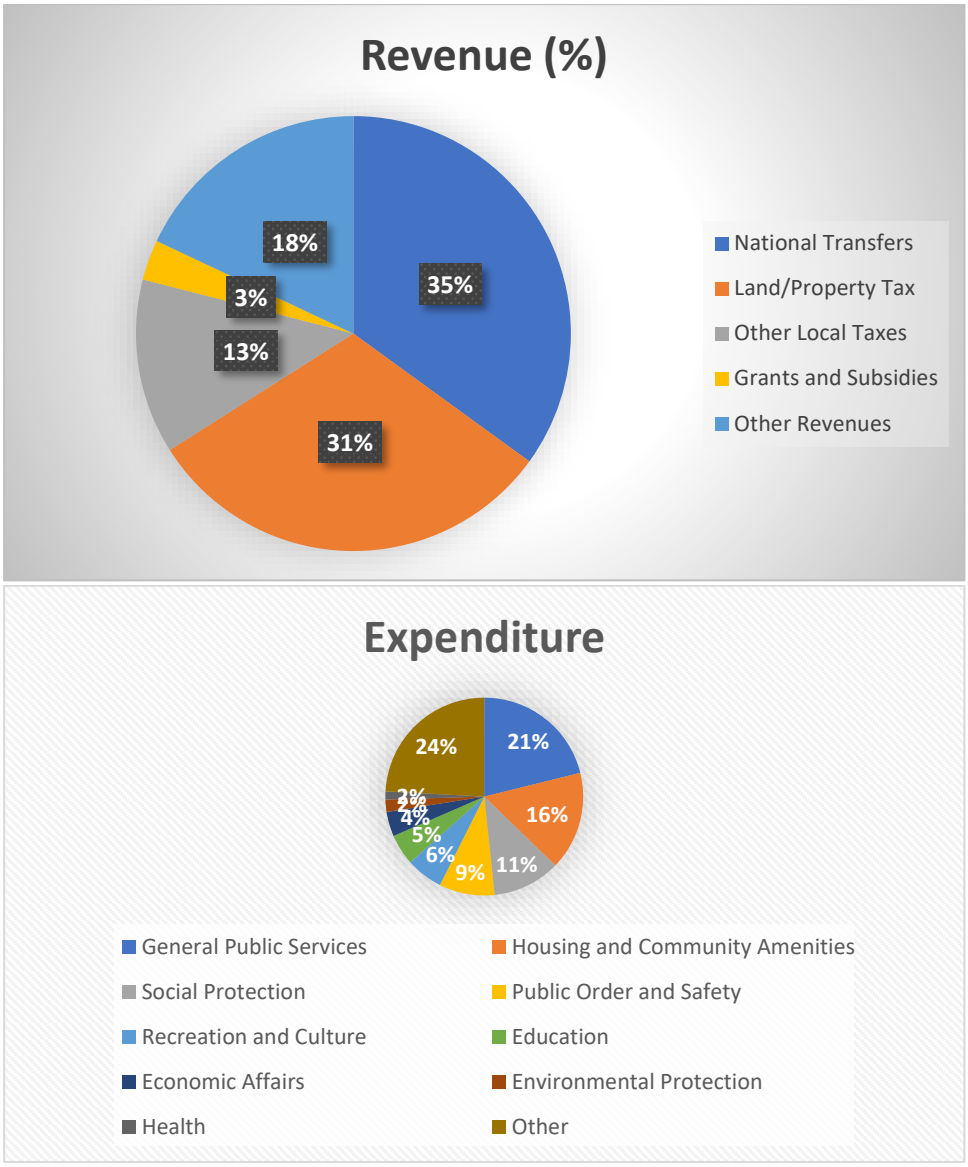

Figure 4.8: Composition of Municipal Revenue and Expenditure, Source: (Barcelona City Council. n.d.-b)

We note that 16% of the expenditure budget is allocated to 'Housing and community services', a category that could include investment in sustainable construction and passive houses. However, the relatively low proportion of funds allocated to 'Environmental Protection' (2%) may indicate that additional funds could be allocated to support sustainable construction projects such as Passive Houses. These houses not only reduce energy consumption, helping to alleviate one of the city's main energy costs, but it also offer long term benefits such as reducing carbon emissions and creating a healthier living environment. Consequently, allocating a larger share of the budget to 'environmental protection' and 'housing and community services' could have a significant impact on the uptake of Passive Houses and other sustainable building models.

Finally, the City Council promotes an inclusive housing model that caters to various forms of accommodation, such as affordable rented properties, co-housing, and provisions for special social requirements. As part of a wider social housing project, 3,200 sheltered homes and housing units were either under construction or in the initial stages of development in 2021 (Barcelona City Council, 2021).

The city of Barcelona is a paradigmatic model in the transition to a sustainable energy future. Committed to a long-term strategy to eliminate dependence on fossil fuels, it has introduced various initiatives such as the 2016 Sovereign Energy Transition Plan (TES), which includes a budget of 130 million euros to reach an ambitious goal: 100 per cent of energy produced from renewable and zero-emission sources (Ajuntament de Barcelona, 2016). Other initiatives such as the Renewable Lighting Plan 2018-2020 and the Barcelona Energy Improvement Plan (PMEB) have laid the foundations for greater energy efficiency through technologies such as LEDs and energy consumption meters in residential buildings.

As a confirmation of its strategy, the municipality has expanded the use of renewable energy sources in public infrastructures, as demonstrated by its 10,500 square meter photovoltaic plant that produces 550,000 kWh per year, enough to cover the annual energy needs of around 140 households (Elcacho, 2009). In the transport sector, the public transport company TMB has planned a tender for the purchase of 210 electric and hybrid buses with the goal of converting 50 per cent of the fleet to electric vehicles by 2030 (Barcelona City Council, 2021).

For further advances, the participation in the PRIMA project by IREC (Institut de Recerca en Energia de Catalunya) marks a significant step towards the optimization of energy infrastructures, with a budget of EUR 300,000 spread over four years (Ajuntament de Barcelona and Gerència d Àrea d'Agenda 2030, Transició Digital i Esports. 2020). All this has helped position Barcelona as the 14th most sustainable city in Europe in 2021 (Ajuntamento de Barcelona, 2022).

In the transition towards sustainable urban planning, Barcelona offers an exemplary case study through its multi-dimensional approach. The city boasts a significant presence of green areas, with 620.3 hectares of urban parks and a green space of 17.3 m² per inhabitant (Ajuntamento de Barcelona, 2022). In addition, projects such as the 'Nature Plan 2021-2030' aim to extend these areas, with an investment of EUR 6.15 million to improve 20 gardens and add 160 hectares of green spaces (Barcelona City Council, 2021).

In the specific context of the 22@ District, which covers an area of 1.9826 km², the focus was placed on various aspects of sustainable urban development (Geropanta & Ghosh, 2020). The redevelopment of 4,600 industrial-era housing units, coupled with the construction of 4,000 new affordable housing units, improved the attractiveness and livability of the district. The focus on environmental sustainability has resulted in environmentally friendly architecture and efficient spatial planning, also financed by the private sector (HEC Paris, 2021). This has generated a dense urban environment that facilitates interaction between different actors, contributing to the economic and social sustainability of the project.

However, Barcelona has a gap in public housing, owning only 1.5 per cent of its housing stock as public property, a significantly lower percentage than Berlin's 28 per cent (Glasco, 2019). Furthermore, the

Barcelona Renewable 2030 project, with a budget of EUR 2.1 billion, aims to fill these gaps through urban redevelopment and regeneration (EU Next Generation).

In terms of future improvements, the degree of effectiveness of private sector involvement policies could be explored, analyzing the balance between development and sustainability. Further studies could also investigate the social impact of such initiatives, assessing how they respond to the needs of local communities.

In the examination of water management in the Barcelona Metropolitan Area, various crucial factors arise. Initially, water supply and demand are perilously balanced. Demand stood at 592 Hm3 in 2007, whilst available sources provided 611 Hm3, wherein 85% originated from surface water, and the remaining 15% originated from groundwater (Saurí, 2019). The vulnerability of this system was emphasized in 2008 as a year of drought lessened the reservoirs to 20% of their capacity, thereby necessitating the implementation of emergency measures.

In relation to pricing, there were significant alterations to the progressive block system between 2007 and 2013, resulting in a 50% increase in the cost of each block. These adjustments caused a respective 20% and 12.5% reduction in water consumption for industrial and commercial purposes (Saurí, 2019). Despite this low usage, 10% of households in the region are presently struggling with 'water poverty' (Saurí, 2019; The Decline of Water Consumption in Cities of the Developed World: Insights from Spain, 2019).

Technological innovations, including remote irrigation managed through sensors and IoT, have resulted in a 25% decrease in water consumption, saving £550,000 (Logitek, 2014; Morningstar, 2023; Brears, 2023; Libelium IoT, 2023). Additionally, initiatives like the IBATHWATER project endeavor to mitigate the environmental effects of rainwater (Barcelona City Council, 2021).

Water consumption per resident is a vital gauge of a city's water resource sustainability. It imparts the degree of effectiveness and responsibility in water usage and can be used to evaluate the efficiency of water management policies. This criterion is particularly significant in the context of the Barcelona Metropolitan Area due to the area's water-related obstacles, including water resource overuse and vulnerability to drought.

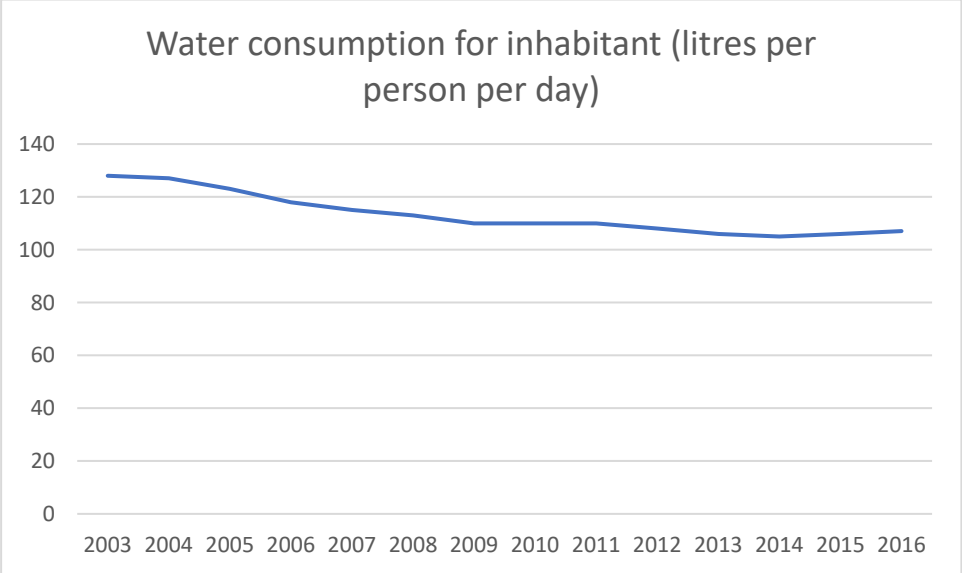

Figure 4.9: Water consumption for inhabitant, Source: (Saurí, 2019).

Over the period from 2003 to 2019, data reflecting water consumption per inhabitant in Barcelona demonstrates a clear overall downward trend. Specifically, the quantity consumed per inhabitant declined from 128 liters daily in 2003 to 107 liters in 2019. The most conspicuous decline occurred over

the period from 2003 to 2006, with the consumption level dropping from 128 to 118 liters per day. After 2006, the reduction continued in a steadier manner, reaching a plateau of around 110 liters per day from 2011 to 2013, and declining further to 105 liters per day in 2017. Interestingly, over the next two years, consumption increased slightly, reaching 107 liters per day in 2019.

The previously observed downward trend could be attributed to a variety of factors, such as rising tariffs, public awareness campaigns and the adoption of more efficient technologies, as highlighted elsewhere in our analysis. Nevertheless, the slight increase in consumption towards the end of the period may indicate a requirement for further investigation to comprehend the dynamics at play.

In summary, the management of water in Barcelona is an intricate system that endeavors to stabilize supply and demand in the face of obstacles such as drought, water scarcity, and the requirement for sustainability. Approaches include progressive tariffs, cutting-edge technology, and public-private partnerships, as solutions to tackle these challenges.

According to (City, 2022b), Barcelona and Munich are collaborating to achieve certification as Zero Waste Cities, a European award coordinated by the Mission Zero Academy (MiZA) and supported by Zero Waste Europe (ZWE). The city has set clear goals for the near future, including a reduction in municipal solid waste and a target collection rate of 67% by 2027, surpassing the European average of 48%. Furthermore, it is expected that there will be a per capita waste generation of 427 kg per year by 2027.

The strategy's exemplary feature is that of adopting a smart waste collection scheme. Dumpsters are fitted with detectors and a wireless device that checks the amount of waste and transmits a signal when it approaches full capacity. This optimizes the waste collection procedure (Smart Waste Management with Sensorik, 2018). This initiative has resulted in a 20% decrease in the number of lorries required for waste collection (Morningstar, 2023).

In 2016, Barcelona implemented a Zero Waste strategy to elevate the standard and diminish the amount of rubbish produced. Alongside certification, the strategy focuses on four facets: waste reduction, reuse, better selection of waste and community participation.

The Barcelona Waste Management report details the strategy's aims and implementation. The waste management trend from 2013 to 2022 in the city of Barcelona is presented in the accompanying chart. Through six primary indicators - total waste generated, total waste disposed of, energy recovery, recycling, composting, and mechanical-biological treatment (MBT) - this text aims to outline the effectiveness of the city's environmental policies and technological initiatives. This multidimensional approach not only enables an assessment of progress made over the years but also identifies areas that could benefit from further improvement.

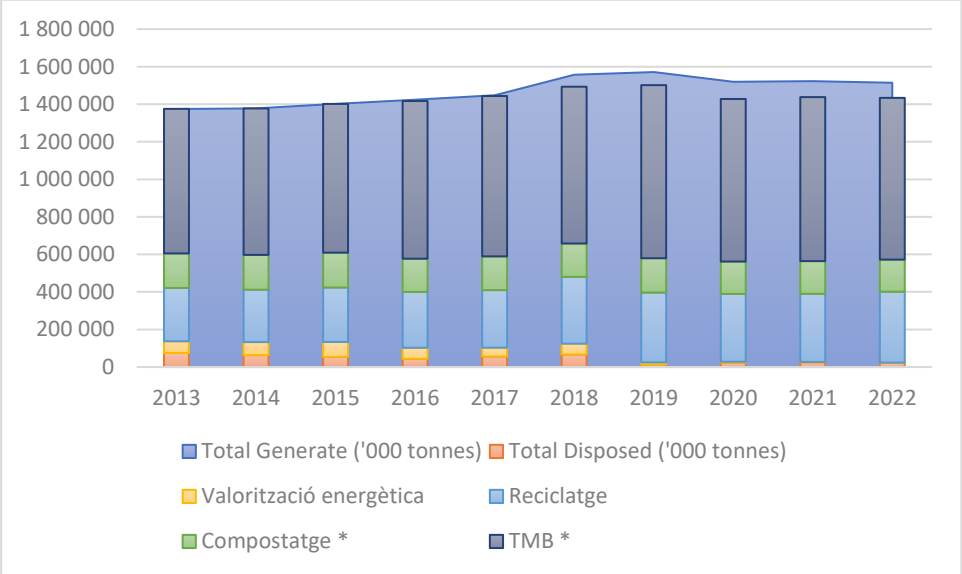

Figure 4.10: Evolution of Waste Management in Barcelona (2013-2022), Source: (Waste - L'àrea Metropolitana - Àrea Metropolitana De Barcelona, n.d.)

The chart depicts the progress of waste management in Barcelona between 2013 and 2022, highlighting metrics like total tones generated and disposed of, energy valorization, recycling, composting and mechanical-biological treatment (MBT). A favorable shift in waste disposal is apparent, with a significant reduction in 2019, and a surge in recycling and composting initiatives. While the total amount of waste generated has been increasing, reaching a peak in 2019, the amount of waste disposed of has been decreasing, which highlights the effectiveness of alternative disposal strategies. The energy utilization levels have fluctuated, with a significant decrease observed in 2020 and 2021, indicating a shift in strategy or external influences. Lastly, mechanical-biological treatment (MBT) has been growing until 2019 prior to stabilizing, indicating an investment in more advanced technologies.

Barcelona, a large metropolitan center situated in the Mediterranean, confronts substantial challenges linked to air pollution. Though the city has implemented various technological measures to enhance efficiency and quality of life, the general situation remains troubling (Grimaldi, V. Fernandez, 2017). Pollution in Barcelona is primarily caused by urban and regional traffic as well as port activities. The port's emissions can contribute up to 50% of the overall nitrogen oxides (NOx) levels in the city.

The gravity of the situation is underscored by Friends of the Earth's 'D-' rating conferred on Barcelona in 2015 (Friends of the Earth, 2015). Additionally, in 2019, the European Commission cited Spain for non-compliance with air quality standards and pinned the blame partly on Barcelona (European Commission, 2019). Air monitoring stations in Barcelona recorded NO2 levels above EU limits until 2019, despite adhering to regulations set forth by the World Health Organization and the European Union.

However, recent efforts to reduce pollution require recognition such as the creation of the Low Emission Zone in 2020 and the Plan for Air Quality Improvement (PMQAB), which promote other environmental initiatives within the city (Ajuntament Barcelona, 2020; Barcelona City Council, 2021). These plans are backed by a network of 11 monitoring stations that measure multiple hazardous pollutants (Air Quality, n.d.).

A positive development made by Barcelona is the establishment of an online portal focused on air quality. The portal aims to offer citizens prompt and comprehensive updates on current pollution levels, including information about PM 2.5. Its purpose is to enhance public understanding of the issue while presenting recommendations on how residents can safeguard themselves during times of intense pollutant concentration.

Encouraging awareness and education among citizens is essential for promoting long-term change. This initiative demonstrates the local authorities' dedication to providing informative resources that can enhance individual and collective decision-making regarding health and well-being.

The purpose of this diagram is to offer a comprehensive analysis of the level of pollutant PM 2.5 in Barcelona throughout 2022:

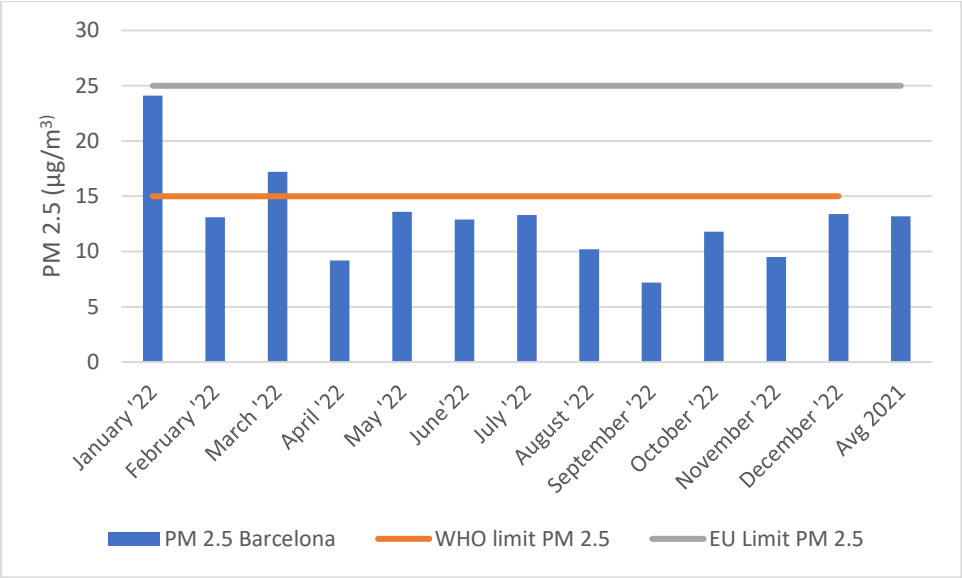

Figure 4.11: Comparative Analysis of PM 2.5 Levels in Barcelona against WHO and EU Guidelines (2021-2022), Source: (*Article Detail*, n.d; World Health Organization: WHO, 2022; *EU Air Quality Standards*, n.d.; *World's Most Polluted Cities in 2022 - PM2.5 Ranking | IQAir*, n.d.).

The graph illustrates a substantial disparity between the PM 2.5 levels monitored in Barcelona and the standards prescribed by the WHO. As per the 2021 WHO guidelines, the yearly average concentration of PM 2.5 should not surpass 5 µg/m³, and 24-hour mean exposures should not top 15 µg/m³ for more than 3-4 days annually.

Only September in Barcelona achieves a PM 2.5 level (7.2 µg/m³) that is slightly proximate to the WHO ambition, while levels far exceed the constraints in all other months. It is concerning that in January, the PM 2.5 level is 24.1 µg/m³, nearly five times over the annual limit advised by the WHO.

These figures indicate that Barcelona has a significant distance to cover in order to satisfy the stricter worldwide criteria for air quality. Such high levels of PM 2.5 represent not only a potential threat to public health, but also an indication that more stringent measures and immediate action may be needed to mitigate the sources of pollution. It is encouraging to note that Barcelona has managed to comply with the EU's less stringent standard of 25 µg/m³ daily, albeit marginally reaching it in January. Additionally, the limit of 20 µg/m³ in the 3-year average is believed to be met, but verifying this assertion is difficult due to a lack of data.

4.2 SINGAPORE

Within the global discourse concerning the development of smart cities, Singapore stands out as an exemplary case study. The city-state embarked on its intelligent city transformation in 2006 with the inception of the Intelligent Nation 2015 (iN2015) plan. This ambitious program aimed to propel the country towards an information and knowledge society through the implementation of technological innovations such as ultrafast broadband and the digitization of government services (Snow, 2021). Unlike Barcelona, which has been on a comparable trajectory only since 2011, Singapore has been a pioneer in integrating smart technologies into vital sectors like infrastructure and transport.

Singapore is renowned for its diverse culture and creative urban planning solutions, and it is one of the happiest countries globally. Additionally, the country has received further acknowledgement for its citizens' well-being, highlighted by its top ranking in the World Bank's Human Capital Index 2020. The emphasis on quality of life is apparent in the infrastructure sector through initiatives like the

establishment of the Infrastructure Exchange Asia in 2017, a financial center specifically for infrastructure matters.

Even though Singapore is a rapidly developing smart city with significant growth in gross domestic product, it encounters noteworthy challenges. Nevertheless, despite Singapore's swift evolution into a smart city and remarkable growth in gross domestic product, it is beset by significant difficulties, among them immigration concerns, income inequality, and soaring living costs. Furthermore, the city-state is the biggest port in Southeast Asia and the 56th biggest emitter of carbon dioxide in 2020, suggesting a noteworthy environmental impact (Statista, 2022).

With an ever more urbanized world, Singapore's situation presents valuable insights into the compatibility of technology and sophisticated urban planning with multifaceted social and economic hurdles.

4.2.1 Economics

Singapore is a remarkable example of economic growth and development in the modern world. In recent decades, the city-state has made significant progress in several economic sectors, including manufacturing and financial services. However, the economic landscape of Singapore is constantly evolving, and the current dynamics signify a critical phase in its growth trajectory.

Since 2010, the economic restructuring of the country has progressed favorably, marked by expanded diversification and specialization in sectors with high value-added, according to the 2018 report of the Ministry of Foreign Affairs. This coincides with the international trend towards the fourth industrial revolution, where economies are undergoing radical transformation via innovation and digitization (Schwab, 2016).

Despite these positive developments, the situation in Singapore is complex due to numerous economic and social issues. According to a survey, the primary concern is the cost of living and increasing prices, with 38% of respondents expressing this worry. Unemployment and the general economic situation come after with 31% and 27% corresponding. These statistics indicate a growing economic uncertainty, thereby necessitating the implementation of more specific policies to address these concerns.

Regarding fiscal sustainability, the debt-to-GDP ratio remains a crucial metric. Although Singapore usually receives commendations for its sturdy fiscal stance, recent investigations by Sieveneck et al. (2022) reveal a likely growth in the debt-to-GDP ratio within the period under observation. For instance, while the ratio was at 132.8% in 2019, it only slightly reduced to 131.0% in 2021. This slight contraction should not be interpreted as evidence of stability.

Singapore is now a leading global center for innovation and entrepreneurship, ranking ninth in the Global City Index 2022 (A. Singapore is now a leading global center for innovation and entrepreneurship, ranking ninth in the Global City Index 2022 (A. Singapore is now a leading global center for innovation and entrepreneurship, ranking ninth in the Global City Index 2022 (A. T. Kearney, Inc 2022). The country is experiencing strong growth in its start-up ecosystem with over 4,000 start-ups, 20 of which are unicorns operating in the Southeast Asian region, and with 4795 start-ups, 523 investors and 247 incubators and accelerators according to Startup SG. Singapore's significance in this field is undeniable. In contrast to other cities, such as Barcelona, Singapore stands out in science and technology rankings. As an example, it ranked 33rd in the 2022 Top 100 S&T clusters, with 4.37 PCT applications and 35.483 scientific publications (Sieveneck et al., 2022).

The government's dedication is apparent through a range of actions. Established in 2015, the Committee for the Future Economy (CFE) concentrates on creating prospective economic policies,

particularly for business innovation. In 2017, initiatives like 'Adapt and Grow' helped more than 24,000 individuals gain employment, with over 50% of them being professionals, managers, executives, and technicians (Ministry of Foreign Affairs, 2018). In addition, the one-north district is a hub for research and development, with more than 250 companies, 600 start-ups, and 16,000 scientists, researchers, and innovators calling it home. Singapore has also boosted public investment in R&D, from S$2bn in 1991 to S$19bn between 2016-2020 under the RIE2020 Plan.

This supportive business climate is sustained by several factors, such as an attractive tax system, substantial state funding, and abundant venture capital. Singapore outperforms its regional counterpart with an average business establishment time of 1.5 days, compared to the average of 34.9 days (World Bank 2020; Statista 2021). Singapore's Economic Vision 2030, announced in 2022, seeks to establish the city-state as a worldwide centre for commerce, creativity, and qualified professionals in cutting-edge production (Ministry of Foreign Affairs 2023).

However, although successful, challenges such as the lack of proficient IT engineers and developers persist. Nevertheless, this trend is changing as an increasing number of graduates are choosing to pursue careers in start-ups, implying positive signs for future entrepreneurial innovation (Pangarkar and Vandenberg 2022).

The following table presents an overview of the distribution of the number of establishments in different business sectors in Singapore. The total number of establishments is 226,600. The figures are represented as a percentage of the total

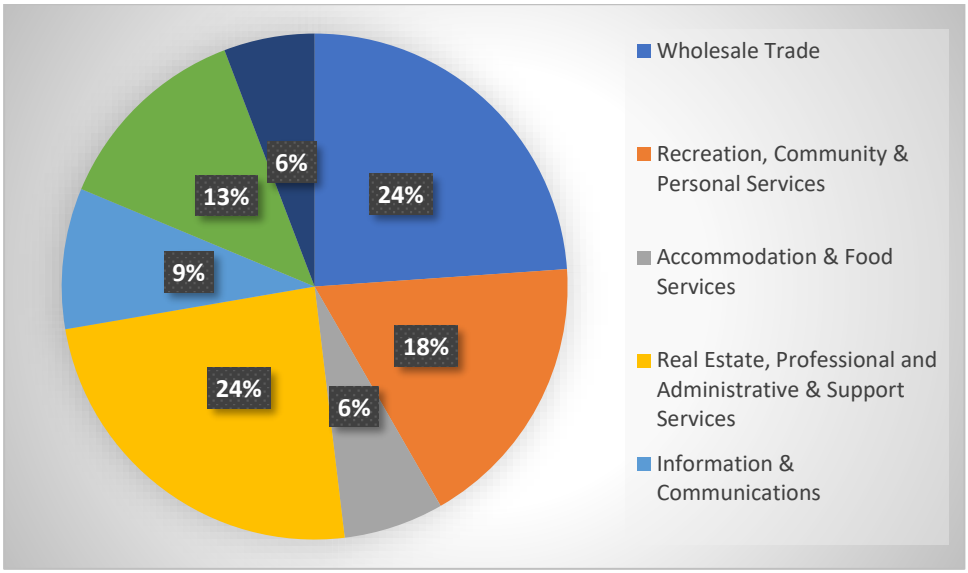

Figure 4.12: Distribution of the Number of Establishments by Sector of Activity in Singapore (%),

Source: (Singapore Department of Statistics. 2023).

From the graph, it is evident that the Wholesale Trade sector has the highest number of establishments, amounting to almost 24% of the total. This is closely followed by Professional, Administrative, and Real Estate Services with 24.2%, and Community, Recreation, and Personal Services with 17.8%. The sectors with the lowest representation are Accommodation and Food Services and Transport and Storage, with 6.4% and 5.8% respectively.

Singapore is widely acknowledged as a benchmark for efficiency and innovation in productivity globally, supported by diverse key indicators and policy initiatives.

At the policy level, Singapore initiated an economic restructuring in 2010 with the objective of enhancing workforce capabilities and encouraging a more forward-thinking economy (Ministry of

Foreign Affairs, 2018). Moreover, the country is ranked amongst the top three nations in the Global Competitiveness Index of the World Economic Forum. Favorable tax rates of 17% for businesses and 22% for individuals contribute towards sustaining Singapore's high level of productivity (Pangarkar and Vandenberg, 2022).

The country's GDP growth rate has consistently remained positive, with a dip to 0% in 2009 that can be attributed to the global housing crisis (Singapore Department of Statistics, 2021).

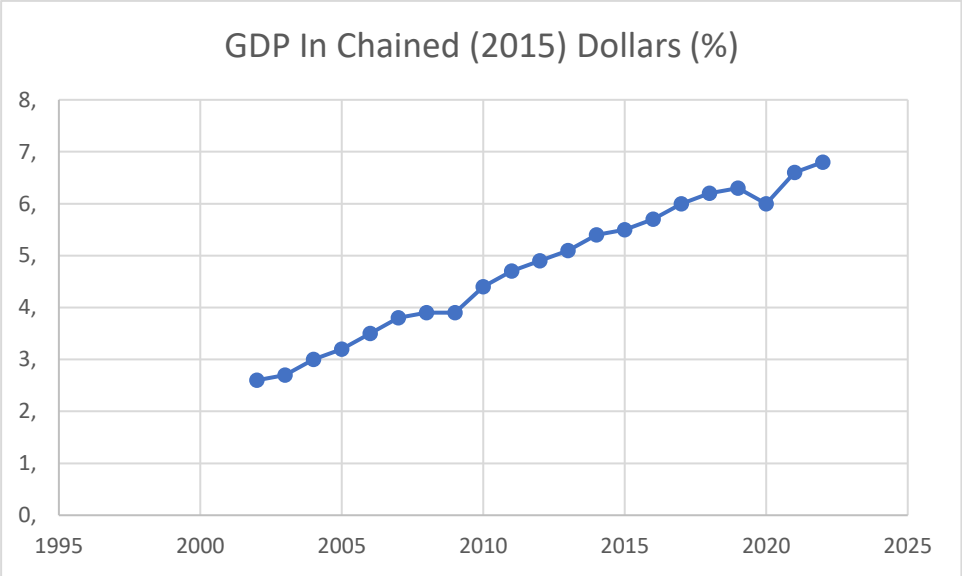

Figure 4.2.1Figure 4.13: GDP Growth Rate in Chain Dollars (2015) in Singapore (2002-2022), Source: (Singapore Department of Statistics. 2023).

The GDP growth rate in dollar terms for 2015 is increasing, signaling a growing economy and effective economic policies.

Nonetheless, there were some halts in the upward trend, more prominently in 2009 and 2020. These establish effects of the global financial crisis, which slowed down the world economy. Interestingly, despite these challenging circumstances, Singapore maintained a non-negative GDP growth rate, indicating the economy's resilience. The most recent data for 2022 indicates a sustained growth of Singapore's economy, despite the COVID-19 pandemic and other global challenges.

The services sector contributed to 70.9% of Singapore's GDP in 2020, emphasizing the importance of a productive industry (International Labour Organisation, 2022). Moreover, Singapore ranked eighth globally for GDP per capita in 2021, being USD 63,474.9 (Statista, IMF, and World Bank data).

However, it is noteworthy that the estimated total labor force in 2021 decreased to 3.54 million (ILO, 2022). These achievements are noteworthy despite the decline.

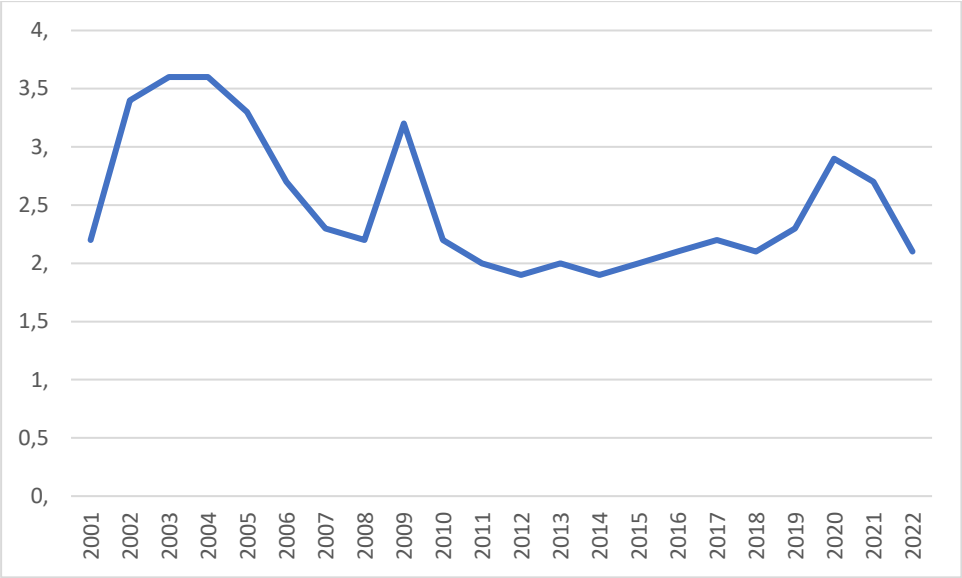

Figure 4.14: Singapore Unemployment Rate (2001-2022), Source: (Singapore Department of Statistics. 2023).

The graph illustrates Singapore's policies' effectiveness in achieving and sustaining a comparatively low unemployment rate. This metric is frequently used as an economic well-being indicator on a global level. Investment in workforce training and tax incentives for job creation are included in Singapore's policies in this area. However, it is crucial to avoid complacency and continue to innovate and adapt policies to maintain a low unemployment rate in the future.

The Adapt and Grow initiatives, along with the Council on Future Economy (CFE), are presently tackling issues such as sluggish productivity growth and adapting to new technologies (Sieveneck et al., 2022). The CFE seeks to achieve enduring, sustainable and robust economic growth by prioritizing a skilled workforce that is predisposed to ongoing education.

Singapore's economic interconnectedness is particularly relevant, considering that two-thirds of its GDP is generated by external demand. This is further corroborated by its strategic focus on international connections, as indicated by the CFE's Strategies for Deepening and Diversifying Global Relationships (Sieveneck et al., 2022). In terms of infrastructure, Singapore is making significant investments in the transport sector, including the airport and a new seaport in Tuas, with the aim of doubling container handling capacity. The rail network is also expanding, from 230 to 360 kilometres by 2030, underlining the importance of physical infrastructure in global and local interconnection (Williams, 2017; Ministry of Foreign Affairs, 2018). The high penetration of information and communication technology, with a mobile phone penetration rate of 149.6 per cent and a wireless broadband penetration rate of 206.1 per cent, is indicative of its digital readiness (Ministry of Foreign Affairs, 2018). Singapore not only holds the position as Southeast Asia's largest port but is also a global financial hub with a AAA rating, underlining its strategic importance (World Economic Forum, 2020; Statista, 2023). In terms of efficiency, Singapore far exceeds the Southeast Asian average, taking only 2 and 3 hours for exports and imports respectively, compared to an average of 63.1 and 64.3 hours in Southeast Asia, and a customs efficiency score of 3.9 against an average of 2.8 in Southeast Asia (Statista, 2023). This picture of resilience and efficiency is further reinforced by the growth of the stock market and service exports, reaching USD 229.5 billion in 2021 (Sieveneck et al., 2022). Singapore's uniqueness as an interconnection hub is highlighted by its positioning as a prime destination for investors and entrepreneurs in Asia, and by initiatives such as BLOCK71 that seek to unite the entrepreneurial ecosystems of China and Singapore (Bloom Consulting, n.d.; Pangarkar and Vandenberg, 2022)

4.2.2 Technology

In Singapore, the government has implemented a comprehensive strategy to tackle the health sector's challenges while simultaneously aligning with SDG3. The initial focus has been on prioritizing advanced technologies, with substantial investments made in telemedicine and health monitoring applications to enhance healthcare accessibility and efficiency (Yoo 2021, 2022; Statista 2023).

Additionally, it has been acknowledged by the government the significance of sustaining accessibility to health infrastructure and ensuring efficient logistics during health emergencies (Kim et al., 2022). Notable actions encompass the creation of intelligent dwellings that feature sensors and IoT devices, employment of machine learning algorithms to anticipate complications related to diabetes and plans to curtail waiting times at pharmacies through automation (HEC Paris, 2021).

These measures are of particular significance given the latest statistics - approximately 40% of water consumption in Singapore comprises recycled water, while the healthcare sector employs close to 96,000 individuals. The city-state confronts a mounting necessity for inventive approaches in preserving a sustainable healthcare system, in view of an ageing population and a surge in chronic illnesses (HEC Paris, 2021). This multifaceted strategy exemplifies the Singapore government's unwavering dedication to attaining SDG3. By synthesizing technical innovation, infrastructural resilience, and prudent resource management, Singapore epitomizes how coordinated efforts can enhance healthcare systems' efficacy and sustainability.

Singapore has shown substantial dedication towards achieving the Sustainable Development Goals (SDGs) through various programs, initiatives, and strategies. For instance, the Sustainable Singapore Blueprint initiative aims to tackle several SDGs, such as SDG 3, SDG 6, and SDG 11 (Barcelona City Council 2021). The Community Safety and Security Program (CSSP) was established to enable community collaboration in addressing safety concerns, in alignment with SDG 16 (HEC Paris 2021).

Notably, the Singapore Civil Defence Force (SCDF) has integrated drones for monitoring outdoor activities, while the Housing and Development Board (HDB) deployed 10,000 surveillance cameras in 2016 (HEC Paris 2021). These technology initiatives align with the Land Transport Authority's (LTA) Intelligent Transport Systems (ITS) program, which employs an advanced vehicle monitoring and recovery system (Ministry of National Development Singapore, 2015).

Additionally, public opinion plays a vital role. As per a report by Accenture Consulting in 2018, 74% of citizens desire increased police employment of CCTV cameras, and 67% feel more secure in their presence (HEC Paris, 2021).

In the context of security and the implementation of the SDGs, the SAFE program (Secure, Accessible, Fair, Efficient) is a crucial factor. The educational initiative motivates students to create concepts and prototypes, improving safety in the city and making a direct contribution to SDG 4 and SDG 11 (MHA Website, 2020).

In essence, the implementation of Singapore's SDGs relies heavily on the use of SAFE, which is further bolstered by a variety of technological advancements and community-based initiatives. Nevertheless, the lack of specific and in-depth data emphasises the significance of further research to provide a comprehensive evaluation of the long-term efficacy and consequences of these measures (Ministry of Foreign Affairs 2023).

In the digital age, transparency and citizen participation are crucial factors for facilitating sustainable urban development (United Nations, 2015; Barcelona City Council, 2021). Singapore has taken significant steps in this regard, implementing multiple programs and initiatives to attain these objectives. One illustration is the 'Data.gov.sg' platform, which provides complimentary admission to more than 2,200 adaptable datasets from 70 government bodies. There are over 90,000 datasets accessible in the economic and socio-demographic fields ((DOS) | SingStat Table Builder, n.d.; Ministry of National Development Singapore 2015).

In its pursuit to transform into a Smart Nation, Singapore has implemented diverse applications aimed at involving citizens in reporting urban issues and overseeing the environment (HEC Paris, 2021; Keong and NGO 2015). Nevertheless, there appears to be a preference for backing businesses, as demonstrated by the Punggol Digital District, which concentrates on enhancing cybersecurity and IoT technologies (HEC Paris, 2021; Von Richthofen et al., 2019).

Regarding the SDGs, Singapore has prioritized certain objectives such as developing sustainable urban areas and communities and enforcing responsible governance (Ministry of Foreign Affairs 2023). Enhancing citizen involvement is an ongoing effort that requires further attention (Rocque 2017).

Emerging technologies, including the conversion of 110,000 lampposts into advanced sensors, are fundamental to enhancing these initiatives, albeit with the potential to raise concerns around privacy and data security (HEC Paris, 2021; Statista 2023).

Singapore is working diligently to promote sustainable, non-motorized modes of transportation. According to data, 22% of Singaporeans utilize walking as their primary method of getting around, whereas cycling is limited to a mere 1% of the population (Deloitte Insights, City Mobility Index, 2019). Despite these statistics, the government has implemented noteworthy measures to enhance accessibility and safety for pedestrians and cyclists. The cycle route network spans more than 460 km at present, with plans to extend it to 1,300 km by 2030 (LTA | Cycling, n.d.). These routes are strategically devised to link commuters to metro stations, bus interchanges and other vital amenities such as shopping centers and schools.

Furthermore, there are ongoing initiatives to establish cycling paths in numerous public housing towns, as well as proposed expansions and upgrades in particular areas such as Ang Mo Kio and Tampines, set to be completed by 2024 (LTA | Cycling, n.d.). These upgrades are intended to offer a secure and accommodating setting for all active mobility users, regardless of age or proficiency. Finally, the data reveals a decline in the typical everyday employment of public transport systems in 2020, succeeded by a resurgence over the subsequent two years. This offers further insight into commuter behavior during the time of COVID-19.

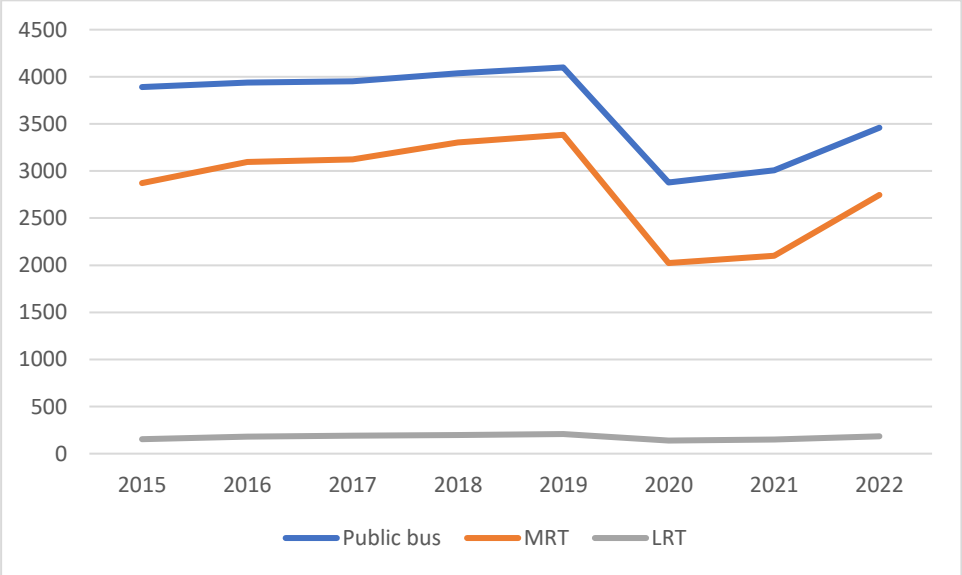

Figure 4.15: MRT and LRT Average Daily Users in Singapore (2015-2022), Source: (Singapore Department of Statistics. 2023).

The chart illustrates the mean number of commuters (in thousands) who used the MRT (Mass Rapid Transit) and LRT (Light Rail Transit) systems in Singapore from 2015 until 2022. It is apparent that both systems experienced a noticeable drop in daily ridership during 2020, which is connected to the effect

of COVID-19 on travel patterns. It is noteworthy that ridership has partially rebounded in the two subsequent years. Nevertheless, up until 2022, passenger figures have not reached 2019 levels, which suggests that ridership has still not fully rebounded.

Education in the Digital Age: Singapore is a leading example of the successful integration of digital education into its education system amid a global trend of interconnectivity and digitalization. The government of Singapore has implemented various measures to ensure access to education for all, regardless of socioeconomic status. This comprises the allocation of subsidies towards pre-school education and discontinuation of mid-year exams for select students. In addition, initiatives like 'Lab on Wheels' and 'PlayMaker Programme' have been introduced to foster technology education starting from pre-school age. (Rocque, 2017; Ministry of Education, 2021).

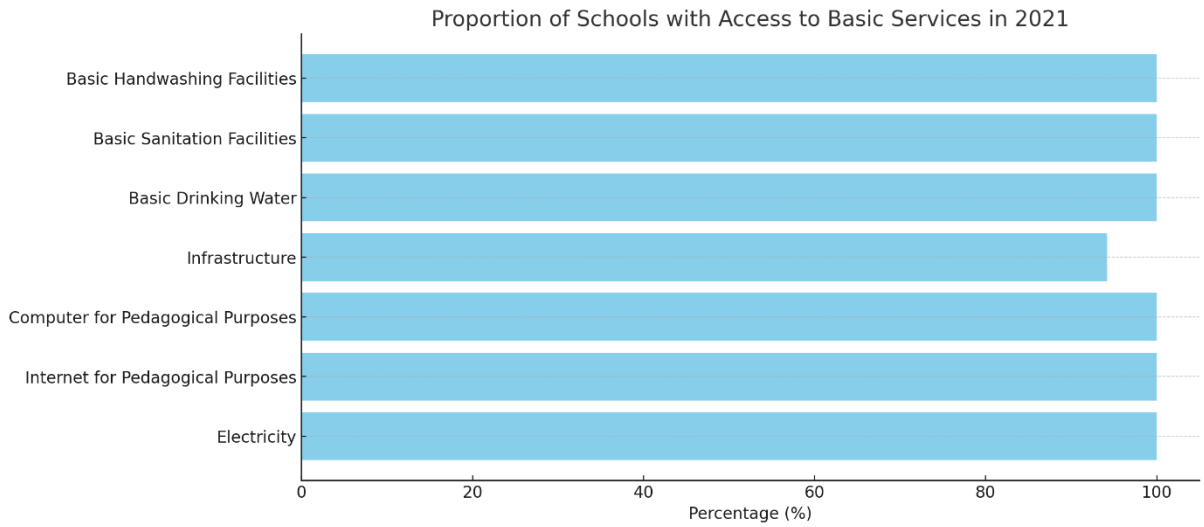

Figure 4.16: Proportion of school with access at basic services in 2021, Source: (Singapore Department of Statistics. 2023).

Furthermore, the government is redirecting their attention towards valuing diverse skills and talents in education. This results in a more practical and customizable curriculum geared towards the world of work. Significant initiatives comprise of "Full Subject Based Banding", providing pupils with the option to concentrate on areas that they excel in, and "SkillsFuture Work-Study" programs that implement hands-on learning (HEC Paris, 2021).

The significance placed on information and communication technology (ICT) proficiencies is underscored by statistics revealing a consistent upsurge in digital competencies amongst young individuals and adults.

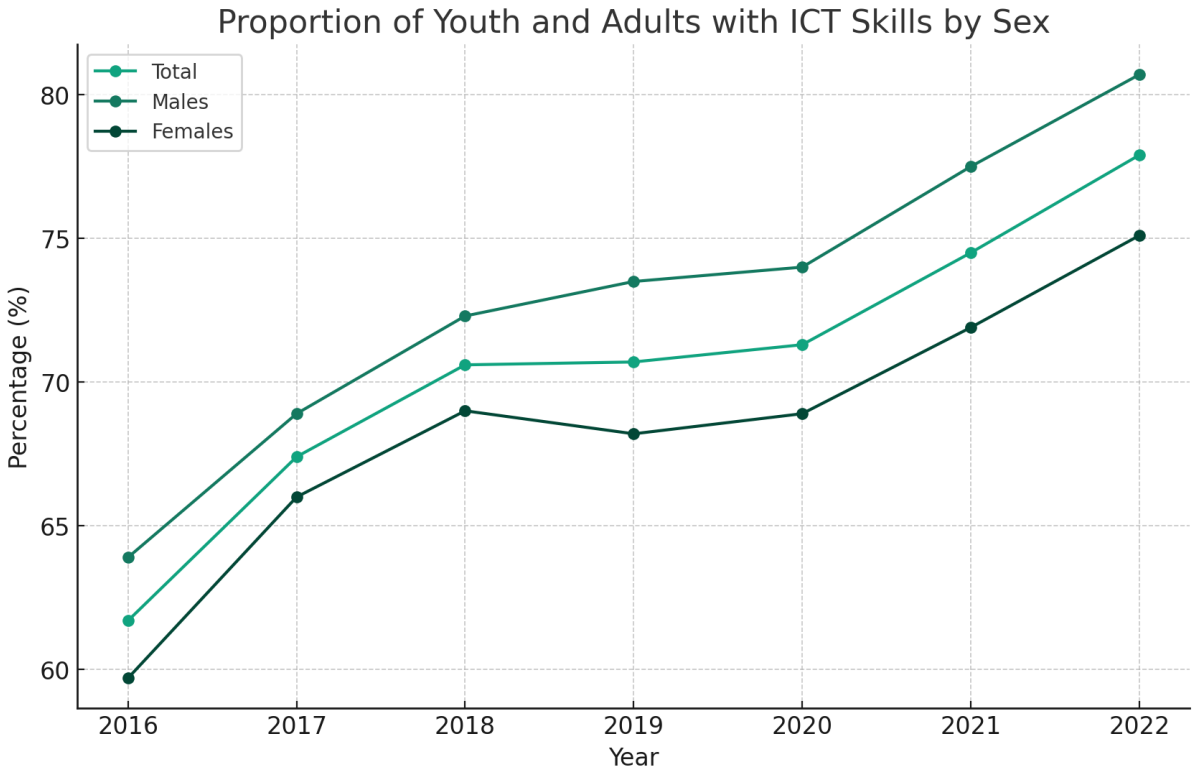

Figure 4.17: Proportion of youth and adults with ICT skills by sex, Source: (Singapore Department of Statistics. 2023).

This rise aligns with Sustainable Development Goal (SDG) 4, which strives to guarantee excellent education, as well as SDG 9, which targets the development of resilient infrastructure and sustainable industrialization (United Nations, 2015).

Concerning infrastructure, Singapore has consistently maintained high rates of broadband service penetration, bolstering efforts to lessen the digital divide and improve access to ICT.

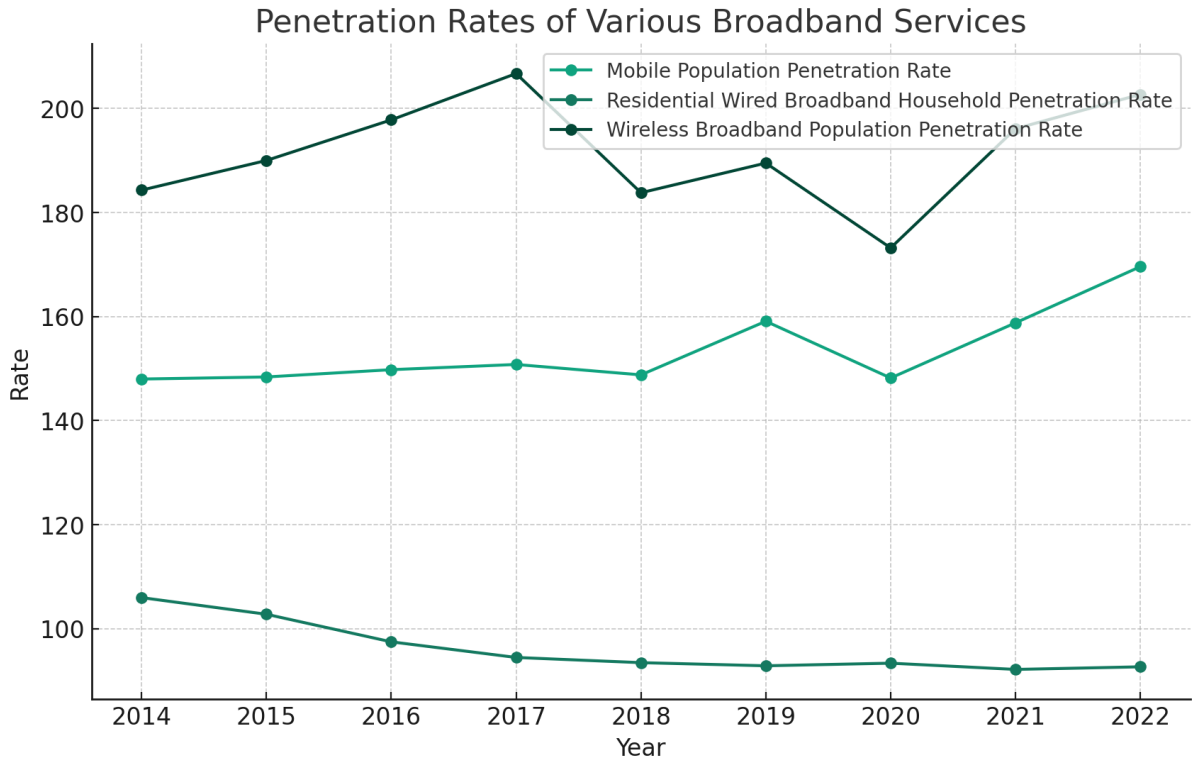

Figure 4.18: Penetration rates of various broadband services, Source: (Singapore Department of Statistics. 2023).

The chart displays how the penetration rates of diverse broadband services have fared between 2014 and 2022. It suggests that there has been a prevalent rise in penetration rates, particularly for mobile broadband.

Singapore has become a model for nations seeking to foster creativity and inclusivity through coordinated public policies and initiatives. A key manifestation of this effort was 2012's Strategic Review on Arts and Culture (ACSR), which aimed to cultivate a nation of knowledgeable, cultured Singaporeans proud of their heritage. The ACSR strives to raise the proportion of Singaporeans attending a minimum of one arts or cultural event annually from 40% to 80% (ACSR, 2012).

Simultaneously, the Singapore Arts Plan (2018-2022) endeavors to encourage creative excellence, inspired by the vision of 'excellence that inspires our people and connects our communities' (Singapore Arts Plan, 2018-2022). These endeavors have been supported by substantial financial contributions, highlighted by the allotment of £200 million for the Singapore Arts Plan spanning 2018-2022.

In the field of social inclusion, the Smart Nation Singapore online platform has implemented several initiatives. These include Home Access, which has granted over 100,000 low-income households' access to priced broadband, the IM Silver program, and the People's Association's Academy for the Elderly (PASA) (Von Richthofen et al. 2019, HEC Paris, 2021). These technological initiatives complement the endeavors of the National Council for the Arts (NAC), which disburses several grants and scholarships to assist artists and arts organizations.

In order to present a more comprehensive outlook, it is imperative to include quantitative data that supports these endeavors. Income statistics, as supplied by the Singapore Department of Statistics, provide additional evidence of the efficacy of these policies.

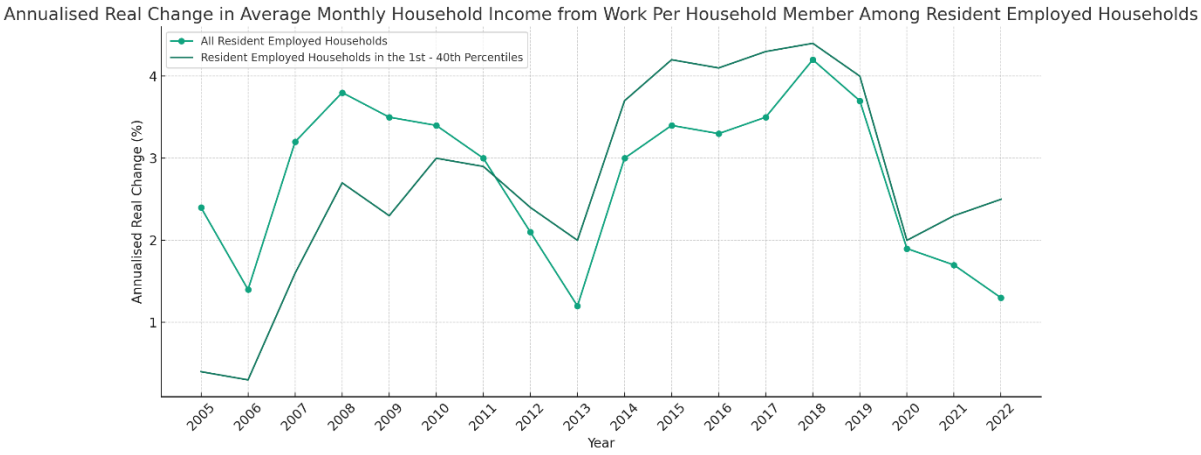

Figure 4.19: Annual real changed in average monthly household income per household member,

Source: (Singapore Department of Statistics. 2023).

This figure displays the annualized percentage alteration in mean monthly labor earnings per household member for all resident working households and those in the 1st - 40th percentile from 2005 to 2022. It is noteworthy that the income growth of households in the 1st - 40th percentile has been higher compared to the overall average, particularly since 2010. This indicates that initiatives for social inclusion are effective in lowering income inequality, in agreement with SDG 8 and SDG 10 (Source: Singapore Department of Statistics).

In the context of smart tourism and cultural events, Singapore is a leading example of excellence due to the Singapore Tourism Board's (STB) holistic and multi-faceted approach. The STB has prioritized labor skills development, working with different stakeholders to train skilled workers in the tourism sector (HEC Paris, 2021). Singapore's Ministry of Foreign Affairs (2018) has created a Skills Framework (SF), outlining career prospects, pathways and necessary competencies.

Notably, the country's strategy emphasizes the interplay between tourism and local culture. The Singapore Tourism Board has collaborated with affiliations like the Chinatown Business Association and the Little India Shopkeepers and Heritage Association to arrange unique cultural occasions such as festivals in Chinatown and ARTWALK in Little India (Rodríguez, 2023).

At the heart of Singapore's ecosystem, there are also programs aimed at ensuring the long-term viability of tourism associations through different funding and support schemes. The TIP-iT program, for example, provides incentives for the development of managerial skills and leadership in tourism businesses (HEC Paris, 2021).

Despite these achievements, the tourism industry presents several limitations, primarily in terms of lacking crucial data concerning sustainability and innovative practices. To address these deficiencies, the sector intends to integrate new governance models and advanced technologies such as big data and artificial intelligence to enhance decision-making and planning processes (Von Richthofen et al., 2019).

Technology is paramount in managing and planning cultural events such as the Formula 1 Grand Prix. Social media platforms and data analytics are crucial tools for improving these events (Cheng & Jarvis, 2010).

4.2.3 Sustainability

Singapore is becoming a leader in sustainable construction, with a particular emphasis on green buildings and passive houses. The National University of Singapore (NUS) hosts the first energy-neutral and 5G-enabled building, functioning as a laboratory for developing sustainable technology solutions.

A Memorandum of Understanding (MOU) was signed with StarHub in 2019 to encourage innovation in virtual reality and artificial intelligence (Huseien 2022).

The Singapore Green Building Masterplan 2021 marks a significant achievement in the country's sustainable building strategy. More than half of the buildings in Singapore have been 'greened' in terms of gross floor area, as reported by the Ministry of Foreign Affairs in 2023. Despite this progress, Singapore is still met with several challenges, including increasing operational costs that stem from factors like the COVID-19 pandemic and the Russia-Ukraine crisis.

Several projects and initiatives aim to tackle the challenges. These include implementing Carbon Capture, Utilization and Storage (CCUS) and launching the Climate Action Data (CAD) Trust in December 2022 to enhance transparency in carbon markets. Additionally, there is a focus on education and training, with a series of programs launched in 2021 to develop capacity in sustainable design and behavioral change.

In the energy transition context, Singapore appears as a paradigm for integrating sustainability and technological innovation. The nation centralized its sustainable energy strategy on a variety of pillars, including solar energy and artificial intelligence, garnering numerous international accolades for its green energy initiatives. This partnership between technology and sustainability is prominently demonstrated through initiatives like 'SolarNova', which seeks to achieve a 350 MWp photovoltaic capacity by 2030. This initiative was implemented by the Ministry of Foreign Affairs in 2020 (Ministry of Foreign Affairs, 2020).

In addition to 'SolarNova', the 'Smart Nation' initiative utilizes emerging technologies like the Internet of Things (IoT) and Big Data to monitor and enhance the efficiency of energy services (Von Richthofen et al., 2019). The implementation of these initiatives has allowed Singapore to accomplish not only the UN Sustainable Development Goals, such as SDG 7, SDG 11, and SDG 13, but also to establish itself as a pioneering figure in ecological city planning and renewable energy technology.

When considering Singapore's strategies for green energy and sustainability, it is pertinent to examine the country's energy source distribution.

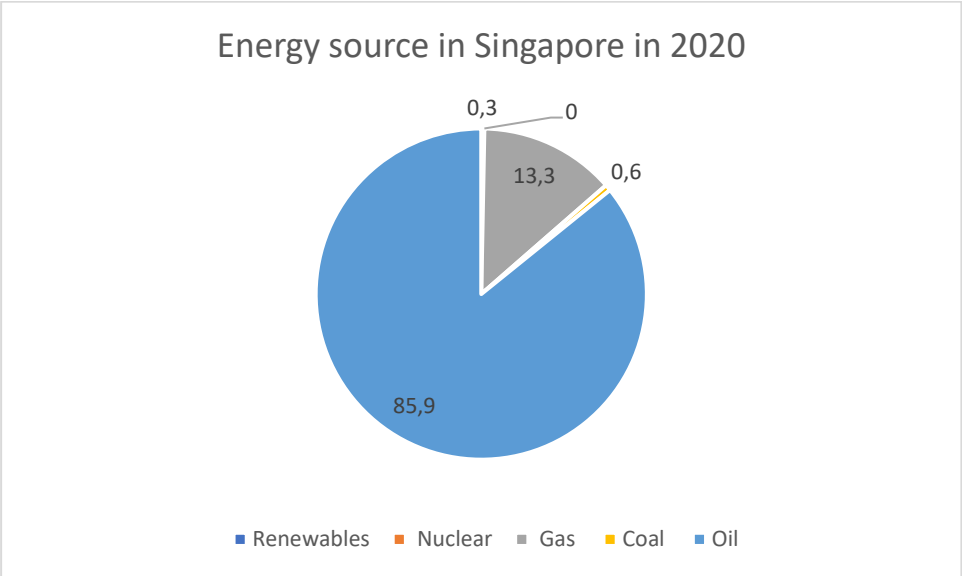

Figure 4.2.2Figure 4.20: summary of Singapore's energy source in 2020, Source:(Statista 2023)

In 2020, Singapore predominantly relied on oil as its primary energy source, representing 85.9% of the energy supply. Conversely, renewable energy only contributed a meagre 0.3%. Such figures highlight the pressing need to attain the Singapore Green Plan 2030 goals, notably increasing the renewable energy share to 30% by 2035.

Gas accounted for a significant 13.3%, although it remains insignificant when compared to oil. Coal and nuclear energy, by contrast, make up negligible proportions.

Nonetheless, there is evidence of a certain inertia in conventional energy sources. According to recent statistics, oil made up 85.9% of Singapore's energy supply in 2020, with renewable sources contributing a mere 0.3% (Ministry of Foreign Affairs, 2023). This disparity underscores the significance of the 'Green Plan 2030', which seeks to boost the percentage of sustainable energy to 30% by 2035 via diversification of energy sources, extensive implementation of solar energy and research into cutting-edge technologies like hydrogen and carbon capture and storage (CCUS) (Ministry of Foreign Affairs, 2023).

Singapore's limited geography and high population density present significant challenges for the nation's adoption of certain forms of renewable energy technology. Nonetheless, the country has shown an unwavering commitment to renewable energy, evidenced by its investment of approximately S$130 million in research and development for low-carbon technologies (Ministry of Foreign Affairs, 2023). Therefore, Singapore constitutes a valuable case study for examining how geographical and infrastructural limitations can be surmounted through technological innovation and long-term planning.

These strategies and outcomes establish Singapore as a quintessential archetype of how a nation can reconcile short-term practical demands with long-term sustainability ambitions. Such practices can yield instructive insights for other cities and regions and warrant thorough academic inquiry for better comprehension of their outcomes and transferability to other settings.

Singapore is a paradigmatic case study in green urbanism, a model for integrating sustainable and innovative technologies into the urban fabric. The Asian city-state has won several awards for its sustainability efforts and is currently at the forefront of projects that define the future of smart cities.

One of the most emblematic projects is Punggol Smart Town, an archetype of a sustainable, technological and prosperous city. This new neighborhood was designed with the aim of minimizing environmental impact using technologies such as the Smart Nation Sensor Platform (SNSP), an integrated national platform that uses sensors to collect data essential for the creation of smart solutions (Smart Urban Initiatives, n.d.). The district has implemented the EcoCampus program, which aims to reduce waste, carbon, energy and water by 35 per cent by 2020 (Rocque, 2017).

Singapore's Housing and Development Board (HDB) also plays a key role in planning, having developed a framework for sustainable development. Some of the tools used, such as the Integrated Environmental Modeler (IEM), allow the impact of environmental factors on the design of open spaces and building layouts to be simulated. This includes analyses of wind flow and solar radiation to identify the most suitable locations for solar panels and outdoor comfort. Such analyses are based on the use of advanced high-performance computing technologies and help optimize the layout and design of buildings (Ministry of Foreign Affairs, 2018).

Despite its achievements, Singapore has some limitations, including its reliance on non-renewable energy sources and issues with waste management. Nonetheless, the government is committed to identifying solutions through upcoming schemes and continuous endeavors. Examples of these initiatives include the use of clever sensors for efficient waste and irrigation management, and the integration of innovative technologies to establish a greener and more enduring environment (HDB | Punggol Northshore, n.d.).

Although Singapore has achieved remarkable successes, it is not without its flaws, as it relies heavily on non-renewable energy sources and faces waste management issues. Nevertheless, the government is taking proactive measures through upcoming projects and ongoing initiatives. For instance, it is using intelligent sensors for waste management and irrigation and adopting technology to create an eco-friendly and pleasant environment (HDB | Punggol Northshore, n.d.).

Water scarcity in Singapore is a crucial concern that necessitates a multifaceted approach for effective resolution. Singapore is deemed the world's most water-stressed nation, ranking 170th out of 190 countries regarding freshwater availability. At the beginning of its independence journey, the country

needed to import water from Malaysia. Additionally, Singapore is susceptible to climate change, which can adversely impact water supply and quality. (Asian Development Bank, 2016) Droughts and heavy rainfall episodes can exacerbate the situation.

The lack of space for constructing further reservoirs is a notable predicament. To overcome this spatial constraint, the city has investigated alternative measures such as water recycling and desalination. However, implementing these methods incurs a significant capital and energy investment (Luan, 2010).

With regards to businesses, Singapore's growing industrialization has resulted in a higher need for water for non-domestic purposes, including industrial cooling and manufacturing procedures. This could potentially cause competition for water between domestic and industrial usage, thereby exacerbating the already critical water scarcity situation (Rocque, 2017).

Nevertheless, despite limited water resources and high population density, Singapore has become a worldwide exemplar for water management. The island-state receives an average of 2,400 millimeters of precipitation per annum, which exceeds the global average of 1,050 millimeters (Ivy Ong Been Luan, 2010; Hec Paris, 2021). This abundance has been strategically utilized by the National Water Authority, PUB, through an integrated approach to water management.

Water consumption per person in households is a critical indicator of urban water resource sustainability. This analysis explores the level of efficiency and awareness in water consumption within a city or country.

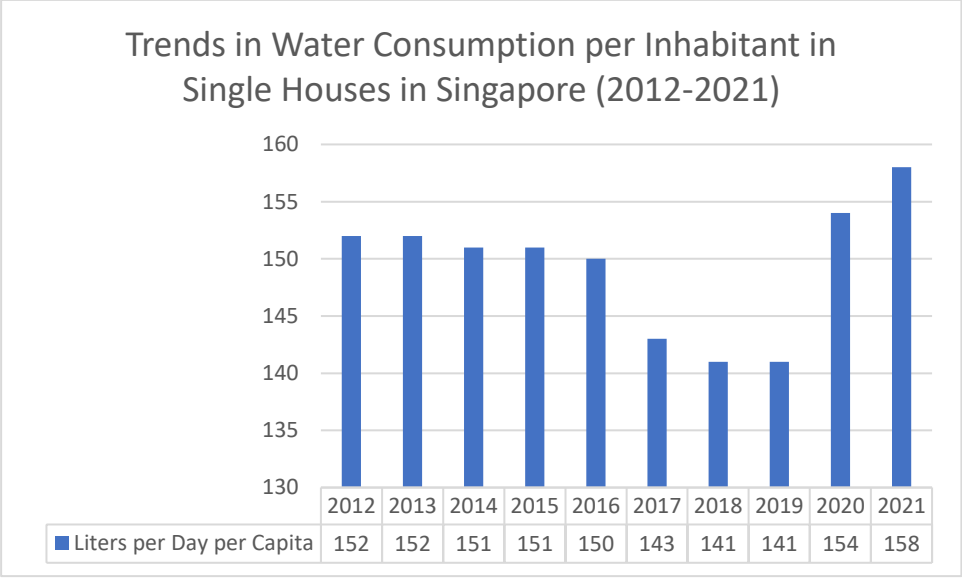

Figure 4.21: water consumption per inhabitant in individual homes in Singapore between 2012 and 2021, Source: (Statista, 2022).

The presented tabular and graphical data demonstrates a fluctuation in water consumption per person in Singapore over a specific period. In 2012, the consumption was 152 liters per day, which gradually decreased to 141 liters per day in 2019. Nonetheless, consumption dramatically increased from 2020, where it reached 158 liters per day in 2021.

This implies that external factors, like climate change, public policies, or exceptional circumstances (such as the COVID-19 pandemic), may have influenced domestic water consumption. A thorough investigation of these data is required to ascertain the underlying causes of such variations and to devise efficient strategies for water management.

Possible improved version in British English: Possible improved version in British English: The reduction in consumption up to 2019 suggests a favorable trend in terms of sustainability and water use

efficiency. However, the rise over the subsequent two years stimulates concern and highlights the necessity for ongoing surveillance and intervention in order to sustain feasible water usage at the goal of achieving 140 liters per day by 2030 (Rocque 2017).

Singapore has implemented innovative methods for creating climate-resilient water sources, such as NEWater and desalinated water. At present, it caters to 40% of the water demand and is expected to increase to 55% by 2060, while desalination accounts for 25% with a projected increase to 30% by 2060 (Rocque 2017; Ministry of National Development Singapore 2015).

Although Singapore is considered the most water-stressed nation in the world, the country has achieved universal access to high-quality drinking water. Smart Water Meters, among other technological initiatives, have enabled more efficient resource management (Smart Urban Initiatives, n.d.).

Future projects include the construction of the Deep Tunnel Sewerage System (DTSS), which is designed to improve the efficiency of wastewater collection and recycling. Furthermore, the government has allocated £670 million towards water sector R&D, highlighting the significance of technology and innovation in Singapore's water strategy.

Nevertheless, there are still discrepancies present. Singapore's susceptibility to adverse weather conditions is due to its dependence on imported water and local reservoirs. Furthermore, the amplified need for commercial water, predicted to rise from 55 per cent currently to 70 per cent by 2060, presents additional hindrances for the city. However, the city is tackling these issues with precise objectives and definite strategies, despite the challenging circumstances.

Singapore is a prime example of efficient waste management, with the aim of becoming a 'Zero Waste Nation' forming a central pillar of the country's national plans, such as the Sustainable Singapore Blueprint (Ministry of Foreign Affairs 2018). In 2017, the city-state produced around 7.7 million tons of waste, leading the government to set an ambitious target of increasing the national recycling rate from 61% to 70% by 2030 (Ministry of Foreign Affairs 2018).

The Semakau Landfill is currently the sole waste disposal facility in Singapore and is projected to be depleted by 2035, underscoring the importance of implementing sustainable waste management practices. At present, the recycling rate for household waste is a mere 21%, which underscores the challenge of effectively recycling and segregating waste.

Nonetheless, the Environmental Protection and Management Act (EPMA) has enabled Singapore to manage hazardous waste effectively through regulations. The launch of the Zero Waste Masterplan in 2019 and the Resource Sustainability Act aim to tackle priority waste streams including e-waste, packaging, and food waste. To optimize waste collection, innovative solutions such as bin-filling sensors and smart card access systems have been implemented (Ministry of Foreign Affairs 2023).

Future waste management in Singapore comprises multi-stream management employing advanced technologies. This entails designs to collocate the Tuas water regeneration plant next to an integrated facility for waste management to optimize land use. Mandatory segregation of food waste from significant waste producers is set to take place in 2024. Besides, the forthcoming introduction of an Extended Producer Responsibility (EPR) system for managing packaging signifies an inventive method of reducing waste (Singapore Ministry of National Development 2015).

Collaborative initiatives have been undertaken through the Singapore Packaging Agreement (SPA), a voluntary pact between businesses and NGOs aimed at minimizing packaging waste. An instance of such an effort is the 'Green Singapore 2030' strategy, which endeavors to decrease per capita waste sent to landfills by 20-30% within the next decade (Ministry of Foreign Affairs 2023).

Singapore's waste collection and recycling services are widely regarded as highly efficient, supported by data provided by the National Environment Agency (NEA). Furthermore, waste disposal has seen a noteworthy 10% increase, while recycling has increased by 26% from the previous year (Ministry of Foreign Affairs, 2021).

The graph depicts the temporal analysis of the total amount of waste generation, recycled quantity and disposed quantity in Singapore between 2017 to 2022. The units of measurement are expressed

in thousands of tons ('000 tons). The presented data is crucial for comprehending how Singapore addresses the waste management challenges, which is a pivotal aspect of urban sustainability.

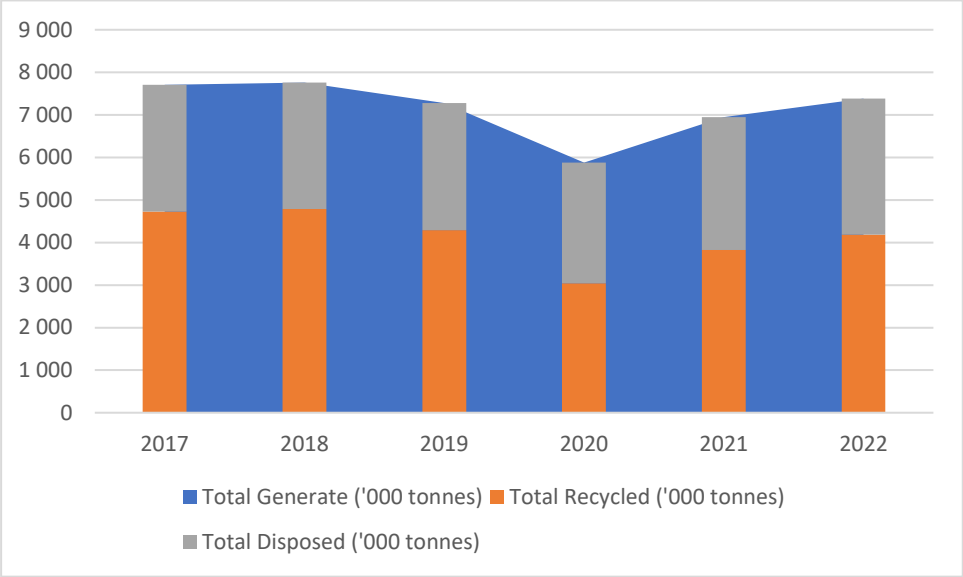

Figure 4.22: Waste Generation and Management in Singapore (2017-2022), Source: (NEA, 2023)

Total Waste Generation: There was a significant reduction in total waste generation in 2020, likely due to COVID-19 restrictions. However, the data indicates a recovery in 2021 and 2022, although it has not yet returned to the pre-pandemic levels of 2017-2018.

Quantity Recycled: The amount of waste recycled displayed a similar trend to total waste generation. The most significant decrease was observed in 2020, followed by a partial recovery in the subsequent two years.

It is worth noting that the amount of waste disposed of has largely remained constant from 2017 to 2022, with a slight increase in the last two years. It is worth noting that the amount of waste disposed of has largely remained constant from 2017 to 2022, with a slight increase in the last two years. It is worth noting that the amount of waste disposed of has largely remained constant from 2017 to 2022, with a slight increase in the last two years. Despite attempts to promote recycling, there have been no significant improvements in the amount of waste being sent to landfills or incinerators.

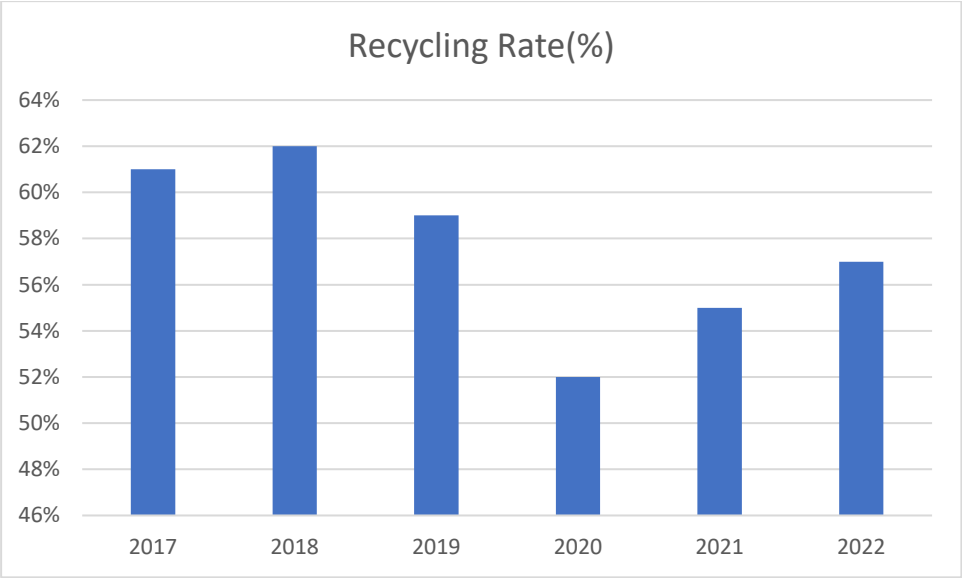

Figure 4.23: Percentage of recycled waste, Source: (NEA, 2023).

It is evident that the implementation of Singapore's policies has had an impact on the recycling rate, as it reached 62% in 2018. However, the recycling rate saw a decline and slump in 2020, where slightly over half of the waste was recycled. Subsequently, there was a recovery, and in 2022, 57% of the waste generated was recycled. While the city has shown signs of recovery, it has not been able to return to pre-Covid levels.

In Singapore, managing air quality is a significant challenge and area of noteworthy innovation. The National Environment Agency (NEA) operates an advanced air monitoring network, which includes 22 fixed stations located across five distinct regions in the country (Environment, n.d.). Nonetheless, despite its efforts, Singapore experienced PM2.5 levels averaging 19 µg/m³ in 2019. This exceeded the WHO recommended standard of 5 µg/m³ by almost fourfold.

The city's air pollution derives mainly from traffic and industrial activities, with the added complexity of intermittent haze episodes linked to seasonal fires in neighboring Indonesia and Malaysia. These factors exacerbate the problem, as documented by the Singapore Air Quality Index (AQI) and Singapore Air Pollution data (IQAir, n.d.; Statista, 2022).

Since 2017, Singapore has implemented stricter emissions standards in accordance with Euro VI regulations and has also adopted cleaner fuel and industrial monitoring technologies (Ministry of Foreign Affairs 2018). Additionally, the country introduced Electronic Road Pricing (ERP) in 1998, which led to a 15% reduction in road traffic within just one year of its implementation. A recently developed ERP system utilizing GNSS technology is currently under development with the aim of achieving more equitable pricing (Ministry of Foreign Affairs, 2018).

Although Singapore has made substantial progress in 2019, shown by the Pollutant Standards Index (PSI) ranking in the 'good' and 'moderate' categories, there are still areas that require attention (NEA Website, 2020). Even though measures like smoking restrictions in public areas have been implemented, they have faced dissent for being insufficient against industrial and traffic pollution.

The long-term objective is to attain air quality standards in line with WHO guidelines.

Comparing Singapore's air pollution data with the benchmarks established by the World Health Organization (WHO) and the European Union reveals notable observations. According to the 2021 WHO criteria, PM2.5's mean annual concentration ought not to surpass 5 µg/m³, and 24-hour average

exposures must not exceed 15 µg/m³ for more than 3-4 days every year (World Health Organization, 2021).

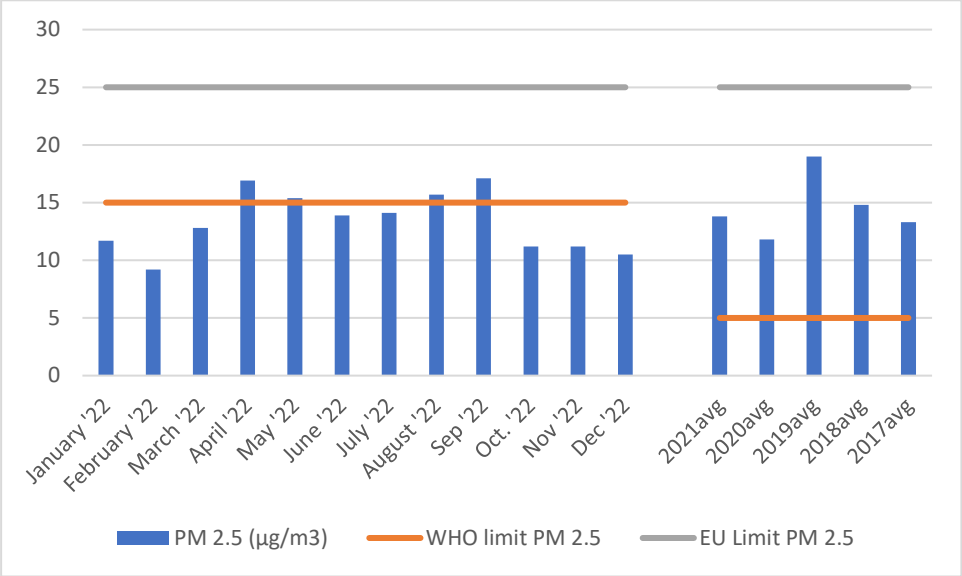

Figure 4.24: Comparison of Singapore, WHO and EU Air Quality Standards, Source: (*Article Detail*, n.d; World Health Organization: WHO, 2022; *EU Air Quality Standards*; *World's Most Polluted Cities in 2022 - PM2.5 Ranking | IQAir*, n.d.).

Compliance with WHO Standards: In 2022, Singapore exhibited fluctuations in PM 2.5 concentrations, with figures ranging between 9.2 µg/m³ and 17.1 µg/m³. These measurements remain within the WHO's 24-hour restriction of 15 µg/m³ (World Health Organization, 2021).

Compliance with EU Standards: Regarding daily exposures, Singapore abides by the 25 µg/m³ threshold, which is less stringent than the EU's limit. However, it should be noted that there have been criticisms regarding the EU standards' effectiveness in safeguarding public health (Anenberg, S. C., et al. "Impacts and mitigation of excess diesel-related NOx emissions in 11 major vehicle markets." Nature, 545(7655), 2017, pp. 467-471).

The graph illustrates Singapore's exceeding of the WHO's daily air quality limit in April, August, and September. It is important to note that the limit of 15 µg/m³ should not be exceeded for more than 3 days per month, which raises concerns about public health and highlights the need for immediate action to reduce pollution levels. The annual average demonstrates how the city doubles the allowed emissions each year of control, reaching almost four times the allowed limit in 2019. Furthermore, although Singapore meets the less stringent European standards, this does not absolve the responsibility to address the pressing issue of air pollution.

5. Discussion

Before beginning the discussion of the case study, it should be considered that the needs of each country and city vary from one to another, and therefore what works in one region or country may not necessarily be successful in another. Any policy and strategy should be based on the individual needs, goals and objectives of a corresponding country and city. While the available resources of a country should not be neglected in policy and decision making progress.(Razmjoo et al., 2022).

Barcelona and Singapore represent unique archetypes in the global innovation and entrepreneurship scene. Barcelona, the Catalan metropolis famous for its cultural and architectural heritage, has emerged in recent years as one of Europe's leading centres for start-ups. The city has seen the birth of seven unicorns, start-up companies valued at more than a billion dollars (Figure 4.1). According to ACCIÓ (the Catalan Agency for Business Competitiveness), investments in start-ups in the city will reach a significant amount of 1.6 billion euros in 2022 (ACCIÓ Regional Government of Catalonia, 2023). In particular, these start-ups focus on areas such as technologies related to Industry 4.0, digital health and sustainable mobility, with a strong commitment to research and development (R&D) activities. In addition, initiatives such as the 22@ district and the Barcelona Activa centre act as catalysts to promote entrepreneurship and technological innovation (Startups in Catalonia - catalonia.com, n.d.). In contrast, Singapore is positioned as a global hub for entrepreneurship and innovation, home to more than 4,000 startups and as many as 20 unicorns. The Singapore government has been extremely proactive in supporting the entrepreneurial ecosystem, as evidenced by initiatives such as the Committee for the Future Economy (CFE) and the Innovation, Research and Enterprise 2020 (RIE2020) plan. These initiatives have led to a significant increase in public investment in R&D and the creation of a favourable fiscal environment for entrepreneurs (A.T. Kearney, Inc 2022; Ministry of Foreign Affairs, 2018).

Both cities possess thriving startup ecosystems and display discernible dissimilarities. Barcelona, with less unicorn companies than Singapore, prioritizes specific market niches and maintains a strong regional foothold. Conversely, Singapore has a more global focus and a substantial presence in Southeast Asian markets, partly due to its geopolitical context and history as a city-state.

Comparing Barcelona and Singapore's urban economies highlights both shared characteristics and noteworthy distinctions. Barcelona's investment in digitization and knowledge-intensive industry suggests a multidisciplinary method of tackling economic challenges, as per Morningstar (2023) and the Barcelona City Council (2020). However, the city's susceptibility to external factors, such as the global financial crisis and the COVID-19 pandemic, is implied by the unemployment rate and GDP growth rate fluctuations (Figure 4.3; 4.4). In contrast, Singapore (Figure 4.13; 4.14) has demonstrated noteworthy economic stamina, kept a low unemployment rate and achieved a positive GDP growth rate even in times of global crisis (Singapore Department of Statistics, 2021; International Labor Organization, 2022). However, Singapore's reliance on highly productive sectors (Figure 4.12) and the decrease in the total labor force for 2021 emphasize the necessity for diversification and investing in human capital (ILO, 2022). Barcelona may benefit from implementing more efficient economic governance mechanisms modelled after Singapore, whereas Singapore could learn from Barcelona's significant investments in the social and solidarity economy.

The comparison of Barcelona and Singapore uncovers striking similarities and differences, facilitating an understanding of how each city has developed its vision for growth. Barcelona, which occupies 26th place in the Global City Index (A. Kearney, Inc 2022), serves as a model of successful integration of global and local connectivity to advance sustainable growth. T. One of the city's strategic initiatives is the 'Barcelona Plan, Global City,' which aims to achieve sustainable development. The Master Plan for International Relations 2020-2023, updated in 2023/2026, is notable for its aim to enhance global collaboration and implement the 2030 Agenda (Plan Director De Cooperación Para La Justicia Global 2023-2026 | Barcelona Ciutat Global, n.d.; Barcelona City Council 2021).

By comparison, Singapore distinguishes itself with its economic resilience and efficiency, serving as a global center for both trade and finance. Its GDP depends mainly on external demand, and its global interconnectedness strategy relies heavily on investment in transport infrastructure (Sieveneck et al., 2022; Ministry of Foreign Affairs, 2018). Digital readiness is a distinguishing characteristic of Singapore, illustrated by high mobile phone and wireless broadband penetration rates. In contrast, Barcelona's approach treats data as a common good (ITU/UN technology agency, 2021; Ministry of Foreign Affairs, 2018).

The disparities between Barcelona and Singapore present abundant prospects for reciprocal knowledge acquisition. Barcelona could assimilate Singapore's operational efficiency, whilst the latter could gain from Barcelona's enhancing local strength. These differences indicate diverse paths to urban success and imply that a dialogue between the two cities could generate mutually beneficial innovations (ACCIÓ - Catalonia Trade & Investment; World Economic Forum, 2020; Statista, 2023).

Both cities display unique modes of development, which are substantiated by their achievements in terms of attractiveness for international investment and innovation. For instance, the technology startup industry in Barcelona is currently flourishing, and its startup ecosystem features a substantial proportion of foreign workers and founders (ACCIÓ - Catalonia Trade & Investment). Correspondingly, Singapore is globally acknowledged as a vital financial hub and a primary port for international trade. Its AAA rating solidifies its reputation (World Economic Forum, 2020; Statista, 2023).

Both demonstrate success in attracting international investment and fostering innovation. The cities' unique approaches to development are evidently effective in promoting economic activity. For instance, Barcelona's technology startup sector is experiencing robust growth and has a significant proportion of foreign workers and founders in its startup ecosystem (ACCIÓ - Catalonia Trade & Investment). Singapore is widely acknowledged as a prominent financial center and a pivotal port for worldwide commerce. This is bolstered by its AAA rating (World Economic Forum, 2020; Statista, 2023).

Barcelona excels in digital, health, and infrastructure security through a multidimensional approach (Safe Cities Index 2021, n.d.). Various aspects of security are strengthened through the utilization of technology, including 5G and blockchain (ITU/UN tech agency, 2021). Singapore, on the contrary, aligns its security strategies with the Sustainable Development Goals (SDGs) by utilizing technology and educational programmed as drivers to enhance security and sustainability (MHA Website, 2020; Barcelona City Council 2021). These dissimilarities imply prospects for mutual learning, where Barcelona could replicate Singapore's cohesive approach towards the SDGs, and Singapore could investigate further measures for digital and infrastructure security.

Distinct but complementary strategies emerge in terms of urban security. Barcelona implements a multidimensional approach, excelling in digital, health, and infrastructure security according to the Safe Cities Index 2021. The city utilizes technology such as 5G and blockchain to enhance various aspects of security, as reported by the ITU/UN tech agency in 2021. In contrast, Singapore aligns its security strategies with the SDG, using technology and educational programmed to enhance security and sustainability (MHA Website, 2020; Barcelona City Council 2021). These distinctions suggest prospects for knowledge sharing: Barcelona could gain insight from Singapore's integrated SDG approach.

In the healthcare initiatives between Singapore and Barcelona, each city displays distinctive strengths. Singapore prioritizes technological innovation, employing approximately 96,000 healthcare workers and incorporating telemedicine and health monitoring applications (Yoo 2021, 2022; Statista 2023; HEC Paris, 2021). Furthermore, the city recycles around 40 per cent of its water, demonstrating a dedication to sustainability. On the other hand, Barcelona has implemented programs like Telecare and Vincles BCN, with a focus on a humanized and community-oriented approach to health. The city aims to reduce maternal and neonatal deaths, as well as the incidence of sexually transmitted diseases by 2030. Both cities are working towards SDG3, but through different strategies which provide chances for mutual learning.

Singapore represents an exemplary smart city model characterized by a robust emphasis on technological projects. The implementation of the 'Data.gov.sg' platform exemplifies how the Singaporean government strives to provide citizens with accessible data (DOS | SingStat Table Builder, n.d.; Ministry of National Development Singapore 2015). It should be acknowledged, nevertheless, that further efforts are necessary to advance public involvement. Although several applications have been launched to engage citizens, the focus has predominantly been on supporting businesses, as demonstrated by the Punggol Digital District (HEC Paris, 2021; Keong and NGO 2015).

Singapore's emphasis on the SDGs, specifically Goals 11 and 16, highlights an effort to promote a balance between technological development and responsible governance. Nevertheless, the focus on technology gives rise to concerns regarding privacy and the security of data (Rocque 2017; HEC Paris, 2021).

Conversely, Barcelona has taken a citizen-centric approach, prioritizing digital law and ethics via tools like Decidim. Barcelona (Interview | UserCentresCities, n.d.). Unlike Singapore, which prioritizes commercial interests, Barcelona emphasizes the active involvement of citizens in decision-making, exemplified by the DECODE initiative (ITU/UN tech agency, 2021).

Barcelona's Open Data platform indicates its commitment to transparency and public participation. The analysis of available datasets shows that there is a considerable effort under the 'City and Services', 'Population', and 'Territory' sectors, whilst the 'Economy and Business' sector requires further effort (Figure 4.5). However, it should be noted that Barcelona has a smaller dataset collection compared to Singapore, which offers over 2,200 datasets on their website with incorporated graph extraction and filtering features. Conversely, Barcelona relies heavily on raw data and requires advanced data management skills. Additionally, the city has limited datasets particularly pertaining to economic trends.

In terms of public participation, Singapore could benefit from adopting Barcelona's citizen-centered approach. Meanwhile, Barcelona could learn from Singapore's business and technology development model to foster innovation.

The two cities offer complementary examples in the realm of digitizing education and integrating information and communication technologies (ICT). While Singapore has implemented a methodical approach to digital education, starting from pre-schooling age via initiatives like 'Lab on Wheels' and 'PlayMaker Programme' Reaching the maximum amount in basic service in school (Figure 4.16) except for the infrastructure that arrive to the 95%(Rocque 2017; Ministry of Education, 2021), Barcelona prioritizes a wider, interdisciplinary focus in higher education, encompassing subjects such as Big Data and sustainability (Grimaldi & Fernandez, 2017). When it comes to personalizing education, Singapore has implemented Full Subject Based Banding to allow students to excel in their strongest subjects (HEC Paris, 2021). Meanwhile, Barcelona is taking steps to broaden educational horizons by prioritizing subjects such as sustainable development and human rights (Barcelona City Council, 2020).

At the infrastructure level, Singapore exhibits elevated rates of broadband service penetration (Figure 4.18), promoting ICT accessibility and you can see the improvement of the knowledge of the population in the Figure 4.17 (United Nations, 2015). Conversely, Barcelona has prioritized urban connectivity with the implementation of Wi-Fi points and IoT solutions, with projects like 'Feel it' utilizing sensors to improve public services (Statista Search Department, 2022). Singapore is directing its efforts towards aligning with the Sustainable Development Goals, particularly through the education sector (United Nations, 2015). Both cities face challenges, such as adapting to the world of work in Singapore and recalibrating urban strategies in Barcelona due to the presence of private mobility services (HEC Paris, 2021), both cities are moving towards a sustainable mobility transition, Figure 4. This represents a social acceptance by the population and an investment by the city in a sustainable mobility transition, Singapore on the other hand needs a greater involvement of the population regarding the use of bicycles in general as 1% use bicycles as a means of transport even though the amount of bike lanes is greater than in Barcelona (LTA | Cycling, n.d.), the population prefers walking and public transport (Figure 4.15).

When comparing Singapore and Barcelona's approach to creativity and social inclusion, a multifaceted approach reflecting the diversity and needs of their respective societies is evident. Singapore has prioritized a vision that combines creativity and inclusion, supported by funding of 200 million Singaporean dollars, as seen in its 2012 Strategic Review on Art and Culture and the 2018-2022 Arts Plan (ACSR, 2012; Singapore Arts Plan, 2018-2022). The Smart Nation platform has implemented initiatives, including Home Access and the Elderly Academy by the People's Association, exemplifying its dedication to lessening digital and income disparities (Von Richthofen et al. 2019; HEC Paris, 2021).

Data from the Department of Statistics in Singapore reveal a positive impact from these initiatives, with a considerably larger rise in income in households within the 1st-40th percentile (Figure 4.19) (Singapore Department of Statistics).

Conversely, Barcelona focuses on an approach centered on the individual, viewing technology as a tool rather than a goal. The Urban Regeneration Neighborhood Plan for 2021-2024 has a budget of 150 million euros and aims to enhance various aspects of life, including creativity and inclusivity. (Barcelona City Council, 2020; Ajuntamento de Barcelona, 2022). The Vincles BCN project and the newly established Smart City campus demonstrate the city's dedication to leveraging technology to assist elderly and disadvantaged communities. (BCN Smart City, 2016; UserCentresCities). The objective of reducing the AROPE rate and the fact that 42% of youth born outside of the country are taking part in initiatives like the BCN Interculturality Program highlights a multifaceted scenario of inclusive practices and diversity (Barcelona City Council, 2020; HEC Paris, 2021).

The context of smart tourism displays a range of strengths, challenges, and prospects. In Singapore, the approach is comprehensive, involving varied angles and driven by the Singapore Tourism Board (STB). The emphasis is on training and augmenting the capacity building of employees in the tourism sector (HEC Paris, 2021). Conversely, Barcelona encountered social and political issues such as the growth of conflict over Airbnb usage. However, the city responded by strengthening regulations, including imposing a fine of €600,000 on Airbnb and doubling the number of inspectors from 20 to 40 (HEC Paris, 2021). Singapore is aiming to improve planning using big data and artificial intelligence (Von Richthofen et al., 2019), whilst Barcelona has already integrated the Internet of Things (IoT) to offer real-time information via a mobile app. Barcelona obtained the Biosphere Platinum certification in 2022 for sustainability (Morningstar, 2023). Singapore lacks information in this field (Von Richthofen et al., 2019). In terms of key indicators, Barcelona displays an increasing tendency regarding the average spending per tourist accommodation and per tourist per day (Barcelona City Council, 2020; Barcelona City Council, 2021). Nonetheless, it tackles concerns linked to the equilibrium between tourists and locals, as indicated by Indicator 894(Figure 4.7), which has surpassed its target.

In terms of sustainable construction, Singapore's objective is to certify a minimum of 80% of its gross building area as green by 2030. Currently, the country has over 94 million square meters of green buildings, which accounts for 34% of the total building area (Ministry of Foreign Affairs, 2018). The Public Sector Program (PSTLES) further demonstrates its commitment to holistic sustainability through its projected electricity and water savings of 15% and 5% by 2020, respectively.

Comparing these statistics to those of Barcelona, the Figure 4.18 shows that the Spanish metropolis has allocated 16% of its municipal budget to 'Housing and Community Services', a grouping that involves sustainable construction investments. Nevertheless, only 2% was assigned exclusively to 'Environmental Protection'. The Barcelona City Council reports the promotion of a housing model that is inclusive and emphasizes the provision of 3,200 sheltered houses. Additionally, 34,000 square meters of housing are currently undergoing renovation, with further housing projects slated to begin in 2021.

Differences in approach are apparent. Singapore places a strong emphasis on green technology and certification as effective tools to encourage sustainable construction, while Barcelona prioritizes sustainable renovation and social housing. Singapore has a prominent institutional influence in innovation, largely attributed to the National University of Singapore (Huseien, 2022). Barcelona, on

the other hand, emphasizes inclusive and sustainable housing schemes by means of public-private partnerships (Rodríguez, 2014; HEC Paris, 2021).

In the transition towards a sustainable energy future, Singapore and Barcelona present themselves as distinctive models, each with individual challenges and prospects. The figure 4.20 shows the energy source in Singapore we can notice a strong dependence on oil and gas in 2020, Singapore has primarily concentrated on emerging technologies and research and development to overcome limitations arising from confined geography and population density (Ministry of Foreign Affairs, 2023; Von Richthofen et al., 2019).

Conversely, Barcelona has taken a participatory and ambitious approach, capitalizing on a more advantageous geographical and climatic context, with the intent of achieving a completely renewable energy mix. This will be achieved through a range of programs, such as the Sovereign Energy Transition Plan (TES) and the Renewable Lighting Plan (Ajuntament de Barcelona, 2016; Elcacho, 2009). Both cities offer valuable insights to each other. Singapore could benefit from Barcelona's participatory approach and greater use of renewable energy, whilst Barcelona can draw inspiration from Singapore's technological innovations and energy efficiency. Ultimately, comparing the two models not only provides a framework for future collaborations, but also deepens our understanding of different approaches to achieving energy sustainability in varying contexts.

Significant strengths and weaknesses are evident in urban environments. Singapore stands out in incorporating state-of-the-art technologies, including the Smart Nation Sensor Platform (SNSP) and the EcoCampus program, exhibiting a substantial inclination towards innovative approaches to realize sustainability targets (Smart Urban Initiatives, n.d.; Rocque, 2017).

However, Singapore faces challenges regarding its dependence on non-renewable energy sources and waste management (HDB | Punggol Northshore, n.d.).

Conversely, Barcelona adopts a multi-dimensional approach to sustainability, investing in public green spaces, as evidenced by the 'Nature Plan 2021-2030' (Ajuntamento de Barcelona, 2022; Barcelona City Council, 2021), and through the sustainable redevelopment of the 22@ District (Geropanta & Ghosh, 2020; HEC Paris, 2021). The city, however, exhibits considerable deficiencies in public housing, with a mere 1.5% of its housing inventory deemed public property (Glasco, 2019).

Both cities face unique obstacles and advantages concerning water management. Singapore's issues of water scarcity are addressed through sophisticated technologies like NEWater and desalination, meeting 40% and 25% of the demand for water respectively (Rocque, 2017; Ministry of National Development Singapore, 2015). However, Barcelona remains susceptible to factors like climate change and growing industrial demand. Effective water management in the city is complicated by drought periods and a delicate balance between supply and demand. The city has witnessed a dip in water consumption per capita from 128 liters per day in 2003 to 107 liters per day in 2016 (Figure 4.9) (Saurí, 2019), while Singapore has substantially reduced its water consumption per inhabitant until 2019, undergoing a surge in 2020-21 (Figure 4.21), it has never reached Barcelona's consumption per inhabitant, also due to the fact of increased water use at industrial level even if the following part needs further study, the causes of this increase, which came at the same time as the pandemic, should be investigated.

Regarding the innovations, including remote irrigation and initiatives such as IBATHWATER, are indicative of progress (Logitek, 2014; Barcelona City Council, 2021). Barcelona's methods to curtail water consumption for Singapore to explore, and Singapore's cutting-edge water technologies and extensive R&D for Barcelona to benefit from.

The two cities exhibit different yet reinforcing waste management models. Singapore aims to achieve zero waste through its 'Sustainable Singapore Blueprint' and enforces rigorous regulations, particularly for hazardous waste (Ministry of Foreign Affairs, 2018). Nonetheless, statistics reveal a halt in waste reduction, signifying the necessity for more competent approaches (National Environment Agency). Barcelona, in contrast, prioritizes innovation and community engagement, exemplified by its smart

waste management system, resulting in a 20% decrease in the number of waste collection vehicles (Morningstar, 2023).

Looking at waste generation: Barcelona (Figure 4.10) we see a slight increase in generation, with a peak in 2019, thanks to the MBT treatment of waste it is able to recycle almost all of the waste generated, Singapore (Figure 4.22) has a higher rate of traditional recycling than Barcelona, not using MBT treatment it has a higher production of non-recycled waste, we see a decrease in waste generation in 2020 during the pandemic in both cities much more marked in Singapore and also note the decrease in the percentage of waste traditionally recycled during this period.

It would be a great cue for Singapore to use MBT treatment to increase the percentage of recycled waste.

Barcelona's multifaceted approach sets noteworthy goals for isolating and reducing waste. This offers an intriguing example of how technology and civic participation can enhance sustainability (Amb.cat). Such provisions can be beneficial for both cities: Singapore could attain prospects from Barcelona's innovative and communal engagement, Furthermore, it would be a good idea for Singapore to use MBT treatment to increase the percentage of recycled waste, whereas Barcelona can attain benefits from Singapore's stringent regulatory framework.

The disparities in methods and achievements concerning air quality are evident. For example, Singapore has an extensively established system of 22 stationary stations (twice as much as in Barcelona) to monitor air quality and utilizes a Pollutant Standard Index (PSI) to gauge several pollutants including SO2, PM10, PM2.5, NO2, CO2, and O3 (Environment, n.d.). The city-state has implemented ambitious measures, such as adhering to the Euro VI emission standards and providing cleaner fuels. As such, the city-state has managed to maintain pollution levels that are comparatively lower in comparison to other cities in Asia (NEA Website, 2020). Nonetheless, in the Figure 4.24 we can notice that in 2019, the average concentration of PM2.5 stood at 19 $\mu g/m^3$, surpassing the recommended limit of 10 $\mu g/m^3$ by the World Health Organization (WHO) (NEA Website, 2020).

Barcelona encounters notable obstacles in combating air pollution due to traffic and port activities (Grimaldi, V. Fernandez, 2017). The city was awarded a 'D-' rating by Friends of the Earth in 2015, and Spain was recently denounced by the European Commission for non-adherence to air quality standards (Friends of the Earth, 2015; European Commission, 2019). However, noteworthy progress has been made through recent measures such as the Low Emission Zone and the Plan for Air Quality Improvement (PMQAB), as indicated by the Ajuntament Barcelona (2020) and Barcelona City Council (2021). In 2022, The figure 4.11 showed that the city marginally adhered to the EU's less stringent standards but fell short of the WHO's more stringent ones. The PM 2.5 level in January was measured at 24.1 $\mu g/m^3$, which is nearly five times higher than the WHO's suggested annual limit (IQAir, n.d.).

Both cities are struggling to meet the standards set by the WHO, Barcelona has made progress by informing citizens and creating a special portal, Singapore has more stationary stations, thus having a more detailed picture of the excess particles present and better knowledge to take countermeasures, it should be noted that air quality during the pandemic period has improved and both cities are maintaining better quality than pre-pandemic levels, however more time will be needed to analyze a comprehensive post-crisis response.

6. Conclusions

The main objective of the thesis was to analyze the economy, technology and sustainability of the study cities Barcelona and Singapore with the aim of having a holistic analysis as complete as possible, the two case studies were analyzed in the factors mentioned in the methodology. The synthesis that was previously explained in the case study section explained in the previous session. This chapter is concerned with specifying and briefly reflecting on the objectives and questions of section 1.1.

O1: Identify the sustainable, economic and technological performance of the case studies.

It was reached in the literature review in section 2.2.1, 2.2.2, 2.3.1, 2.3.1.

O2: Identify the sustainable strategies used by the study cities.

Identified in the chapter 4

O3: To identify the international climate change guidelines, regulatory patterns and performance of the case studies.

Identified in the literature review in the section 2.1

The research questions of this study are as follows:

Q1: How are the case studies performing in the following aspects: sustainability economy and technology?

Answered in chapter 4

Q2: What are the smart strategies used by the case studies to achieve sustainability?

Answered with objective 2

Q3: What are global organizations doing to address the climate crisis, how are the case studies performing?

Answered in the literature review, in section 2.1.

6.1 LIMITATIONS

Metric Differences between Cities: A major limitation is the inconsistency in the metrics used for Barcelona and Singapore. The aim was to provide a holistic analysis, but the difference in metrics made direct comparison difficult and pushed towards a descriptive qualitative approach, supplemented with numerical data where available.

Partial Scope of Analysis: The analysis is inherently partial due to the breadth of the sectors under examination (economic, technological, and sustainable). This study should be considered as a starting point for more in-depth research in each of the sectors.

Use of Voluntary Reports: Although reports provided by cities are generally considered reliable, there is a risk that these sources may have failed to mention or downplayed their weaknesses, leading to biased or favorable representation.

Time-stamped data: Some of the reports and data used for the analysis reach back five years. Therefore, they may not reflect the current situation or the most recent trends.

Absence of a Uniform Baseline for Sustainability: The different sustainability policies and standards between the two cities make a direct comparison in this area complicated.

Cultural and Political Factors: The analysis does not fully consider the cultural, social and political elements that might influence the various aspects of the two cities.

Temporal Limitations: Data are limited to a specific time period and may not represent long-term changes or trends.

Language Barrier: The presence of Spanish-language documents regarding Barcelona may have influenced the accuracy of the analysis.

Cultural and Political Factors: The analysis takes cultural, social and political factors into partial consideration.

Contextual and Geographical Differences: The various geographical and contextual conditions of the two cities were considered, but the inherent diversity may have affected the accuracy of the analysis.

The author tried to keep up with new developments in academia, governments, and industry, but it should be noted that new developments are fast-paced and manifold. This is especially a limitation regarding the Case Study comparison as information collected regarding one market might be more up to date than another.

6.2 RECOMMENDATIONS FOR FUTURE WORKS

Standardization of Metrics: For more effective comparison, future studies should seek to standardize metrics, especially in sectors such as economics and technology.

In-Depth Sector Analysis: Further studies could explore specific aspects within the economic, technology and sustainable sectors to provide a more comprehensive analysis.

Independent Verification of Reports: Analysis could benefit from the integration of independent verification of information in voluntary reports.

Data Update: Using more up-to-date data for a better representation of current conditions and trends is strongly recommended.

Detailed examination of local contexts: Given the geographical and contextual diversity, future research should pay special attention to the local specificities of each city.

Overcoming the Language Barrier: To improve accuracy, the use of professional translation services for documents in languages other than English is recommended.

Adoption of Mixed Methodologies: For a more comprehensive understanding and more robust analysis, it is advisable to use a combination of qualitative and quantitative methods.

6.3 THE AUTHOR'S PERSPECTIVE

The impacts of climate change are increasingly apparent with each passing year. This represents the most significant challenge our generation will confront, we must address to rein in temperatures and restore equilibrium to our planet. The actions we take will determine the well-being of future generations, a responsibility we bear both to ourselves, and to those who come after us.

It is important to acknowledge that the issue of climate change, as emphasized by the study, is currently affecting us, and the effects are being felt. Global institutions recognized this issue in 1992, and attempted to address it with insufficient methods. Until the Paris Agreement in 2015, which sent a powerful message. The 2030 Agenda offers hope for combating the climate crisis, while simultaneously respecting human rights. It is evident that these agreements will prove ineffective, if nations are expected to cease emissions and regress in time. Therefore, as inhabitants of Earth, we bear the responsibility and obligation to transition sustainably by honoring our environment, avoiding waste, facilitating a zero-emission paradigm and utilizing technology and data to achieve this goal.

Studying cities, offers a more comprehensive and holistic way of looking at things, than studying individual technologies, focusing on one element of innovation, and at the same time more detailed than analyzing a nation. I analyzed the economy because cities, like nations, need to be economically strong to attract investment and human capital. These factors are crucial to financing and facilitating the economic transition. Additionally, human capital formation is essential for educating the population, and enabling them to contribute. Technology plays a crucial role in speeding up the technological process, and increasing efficiency within the city. In the analysis I focused on safety, health and events, which are an attraction for the population, a necessity or an activity that the population is unlikely to give up, tourism is an important economic aid especially for Barcelona but it is a major cause of pollution due to: travel, overcrowding and waste generation. Governance is important, as well as transparency and availability of data to allow the citizen, to trust and contribute to the institution, as well as include society to unite it and help creativity to find sustainable solutions, mobility is fundamental to contain emissions.

I then analyzed the most efficient solutions and, immediately, I came across the differences. Where Barcelona aims to renovate, while Singapore is in a sustainable construction phase, where both approaches are bringing positive results, as far as sustainable energy is concerned. Singapore is facing more difficulties; it is still very dependent on oil and gas. Barcelona is geographically advantaged but is technologically lagging behind, all the way it is going a long way by starting a transition long after Singapore, I analyzed the consumption of water waste, and air pollution, to get a complete view of the pollution of both cities, and their progress.

The present scenario is unfavourable for both cities, they are yet to achieve their set targets despite making progress. However, I am optimistic about the technological advancements made in recent years, which may aid them in meeting their objectives under the 2030 agenda. Nevertheless, the Covid-19 pandemic has had a detrimental effect on consumption the percentage of waste recycled. Increasing water consumption in Singapore has had a positive effect on air quality. Barcelona could learn a lot from Singapore technologically. Barcelona's commitment to citizen empowerment has the potential to bring greater inclusion, and valorisation of its resources, particularly with regard to equity in the economic sector. Although globalization can bring faster economic growth.

Fundamental to reducing consumption and facilitating sustainable transition is citizen collaboration. Barcelona is commendable for leaving data sovereignty to the citizen, with the goal of greater equity, even if it results in slower development. Additionally, data transparency and availability are critical aspects. Both cities provide public datasets and reports. However, Barcelona presents more specific reports on initiatives, despite some being in the local language and containing data that is not always complete or relevant. Singapore boasts an outstanding and comprehensive dataset that remains up-to-date. The city, with its Smart Nation project, aims to improve connectivity, and is decidedly more advanced than Barcelona, despite facing greater geographical limitations that pose complex challenges to achieving sustainability.

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