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Smart Cities: A New Path Towards Sustainability

A comparative analysis between smart cities in and outside the Nordic region

by

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Abstract: More and more people are moving to cities all over the world, to look for better educational or employment opportunities as well as take advantage of social benefits and technological network by the cities. Rapidly increasing urbanisation and climate change are creating new challenges for cities to undertake, which is where many cities turn to implementing the smart city concept. The purpose of this study is to give an in-depth insight to different smart city applications in different areas, how they are tackling the issues created by urbanisation and climate change, map out in which areas they are exceeding and where they are lacking. A qualitative comparative study was carried out for this research, where the findings showed that many cities are prospering in the areas such as digitalisation of public services and creating spaces and incentives for collaborations and innovative business creation. However, most of the cases are still lacking at tackling the issues driven by climate change. This thesis gives an insight into four different smart city cases in Nordic and non-Nordic regions, giving further understanding of how the concept of smart cities is implemented in the world.

Key words: smart cities, digitalisation, urbanisation, sustainability, sustainable development

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List of abbreviations and acronyms

AI	Artificial Intelligence
EC	European Commission
GDP	Gross Domestic Product
ICT	Information and Communication Technology
NSCN	Nordic Smart City Network
PV	Photo-voltaic
SC	Smart City
SCG	Smart City Governance
SDG	Sustainable Development Goals
UAE	United Arab Emirates

1 Introduction

In the 21st century, urbanisation and societal transformations have led to new challenges regarding overpopulation, environment, energy use, production and sustainability (Rodríguez-Bolívar, 2015). Cities are one of the main areas contributing to energy consumption, pollution and all in all, climate change (Yigitcanlar, et al. 2019). Urban areas also offer more opportunities for education and work, thus contributing to urbanisation. (Elgazzar & El-Gazzar, 2017)

To tackle the arisen problems regarding urbanisation, the cities are carrying out projects involving high-tech solutions, businesses, the government, and citizens, which is essentially the smart city implementation according to (Elgazzar & El-Gazzar, 2017). The idea of smart cities is new, but rapidly gaining popularity in city development with the end goal of creating cities with efficient and sustainable use of resources addressing the urgent environmental challenges (Rodríguez-Bolívar, 2015).

The concept of smart cities is not a completely agreed on term. There is no consensus amongst researchers, what specific aspects a smart city should possess; however, the core of the idea is to create cities with "more sustainable economic development and a better quality of life (Rodríguez-Bolívar, 2015, p. 1). Another aspect that is generally agreed upon is the use of information and communication technologies within the SC development; digital knowledge sharing platforms, sensors and real-time monitoring is found to establish a more efficient way of urban management (Lim, Edelenbos & Gianoli, 2019). The main ideas that derive from smart city literature are generally related to high-quality of life and environmentally sustainable development, additional aspects are collaboration between citizens and the government, sustainable economic growth as well as facilitating social development (Lim, Edelenbos & Gianoli, 2019).

Smart cities are also strongly related to the Sustainable Development Goals (SDGs), specifically goal 11: sustainable cities and communities (UN, Goal 11: Make cities inclusive, safe, resilient and sustainable, n.d.). This goal embraces the development of sustainable urban

areas that are focusing on problems such as waste management, air quality and reducing the environmental impact of cities (UN, Goal 11: Make cities inclusive, safe, resilient and sustainable, n.d.).

This thesis will therefore explore the realms of smart cities and more importantly the differences found in smart cities in and outside the Nordic region, aiming to answer the question "*How are smart cities today tackling the main challenges driven by increasing urbanisation and climate change?*" The six characteristics that are used for the thesis are smart economy, smart people, smart governance, smart mobility, smart environment and smart living (Giffinger, et al. 2007). The four countries were chosen based on having two of them in the Nordic region, and two outside, which are also outside Europe. All countries however are reported to be the top 50 smart cities in the world based on a report by the IMD (2020) and Eden Strategy institute (2018). This comparative analysis will give a better understanding of how the smart city concept is implemented in vastly different areas, tackling urbanisation and climate change; how they have become the leaders of smart cities across globe and what are the areas, that they are still lacking at.

This thesis will start with giving a background on smart cities, explaining why they are necessary and gaining popularity as well as different associated aspects of smart cities, such as mobility, governance, sustainability, etc. It introduces the problems that urbanisation can, and is expected to cause in the future, and how the smart city concept is expected to tackle it. It will then go on to discuss and give a short background on the chosen cases as well as the methodology chosen, leading to the analysis part. The paper will conclude with a discussion on the analysis results and suggestions for further research.

1.1 Background

1.1.1 Cities and Sustainability issues

Today we witness the era of the Anthropocene, where human impact is considered to have the greatest effect on the health of the earth, according to Yigitcanlar et al. (2019). The authors note that during this era, the man-made environmental issues are becoming increasingly more difficult to handle by the urban administrations. More people moving to cities can have strong

environmental and socio-economic consequences (Yigitcanlar, et al. 2019). Currently cities only take up 3% of the land globally, however they account for 60-80% of world's energy consumption, around 70% of carbon emissions and generate circa 80% of the world's GDP (UN, Goal 11: Make cities inclusive, safe, resilient and sustainable, n.d.).

According to Lombraña and Dodge (2021) currently more than half of the world's population is living in cities. This number is only expected to rise, as by the end of the century circa 85% is expected to live in urban areas. They argue that cities are also more affected by the climate change, as the concrete is more absorbent of heat, than natural ground, which leads to increase of radical weather patterns like heat waves and rapid rainfall. Additionally, with the extreme weather, the immigration from the countryside to the cities increases even more, as people prefer to be closer to better infrastructure systems and essential services (Bennett, Pérez-Bustamante & Medrano, 2017). This problem does not only present itself in developing countries, but also in wealthy countries, where coastal cities are sinking in an accelerated fashion (Lombraña & Dodge, 2021). The fast increase in urbanisation, however, requires innovative ways to target the problems of overpopulation, congestion, resource management and energy production and consumption. (Bennett, Pérez-Bustamante & Medrano, 2017)

The extreme weather patterns are not only a problem of the future but can be seen across the globe already today (Lombraña & Dodge, 2021). According to the Economist (2020), there are wildfires, heatwaves and droughts as well as intense storms and floods happening that are the direct consequence of climate change and increasing emissions. The authors continue that this is mainly because of the high concentration of people in the urban areas. They argue that cities especially need to be reimagined and redesigned to create more circular and sustainable systems instead of the linear consume-waste systems that have been now in place for decades. Climate-proofing the cities is what Robert Muggah (specialist in cities, security and mitigation) calls the new directions cities should be heading in, as adaptation to the already visible climate changes is crucial (The Economist, 2020).

According to the World Cities Report (UN-Habitat, 2020), climate change is to a large extent caused by cities, however, cities are also the main areas experiencing the consequences of climate change. The report clarifier that rising sea levels and extreme weather put the most pressure on coastal cities. According to the report, countries around the world will need to invest

around 1,5 trillion US to improve resilience against climate change and building up new and innovative infrastructure in order to stay under the 1,5 degrees temperature increase globally.

1.1.2 Smart City Concept

According to Anthopoulos (2015) the term “smart cities” is not necessarily a new concept, as it has already been around since 1998. He argues that the concept is not one sided, it ranges from environmentally sustainable cities to ICT environments to urban living labs. Smart cities have now been incorporated into several different fields, such as international organisations like EU, construction companies, ICT industries as well as electronics companies, that are all working to keep up with the new market opportunities (Anthopoulos, 2015).

The smart city definitions differ based on the author or organisation providing the definition. To have a more uniform understanding of a SC for this thesis, a United Nations Economic Commission for Europe (UNECE) and the International Telecommunication Union have created a joint definition for smart cities that is also used for this thesis:

> A smart sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects (UNECE, 2015, p. 3).

The smart city concept has become an attractive solution for urban leaders to fight climate change with the help of technological innovations and therefore achieving cities’ climate targets (Bennett, Pérez-Bustamante & Medrano, 2017). According to Anttiroiko (2015) one of the core aspects that has been focused on since the late 1990s has been digitalisation. The author suggests that this is related to how community informatics and high-tech innovations that is used for urban knowledge-processes. They expand that another important aspect is the user-driven innovations that must be inclusive and integrative. Additionally, the author emphasizes the growing concern around environmental sustainability and how national and global governments can become driving forces of sustainable development. Anttiroiko (2015) argues that there are two general sides of the smart city concept: form- how things are done and

content- how things are created. Therefore, implementing a smart city includes policy design as well as implementation, more specifically platforms that are created to involve citizens or facilitate change but also of the content of the processes (Anttiroiko, 2015). The main goals are often related to using resources sustainably, lowering greenhouse gas emissions as well as ecological impact of production according to Bennett, Pérez-Bustamante & Medrano (2017). However, the authors note that technology alone cannot create the impact that is needed, other investments are necessary, such as investments in social and environmental capitals, and creating a truly holistic view toward smart sustainable city development. Therefore, the smart city concept can tackle several problems of urbanisation besides just environmental sustainability, it can pave way for solutions to inequality, unemployment, energy management etc (Bennett, Pérez-Bustamante & Medrano, 2017).

1.2 Aim and Objectives

The aim of this research derives from a thesis published in Blekinge University by Colldahl, Frey and Kelemen (2013). Their thesis set out to explore the opportunities that smart cities in Europe allow to find solutions to sustainability challenges. The authors used the same smart city framework that has been applied to this thesis and argued that an interesting take for future research would be to examine smart cities outside Europe to compare and contrast the SC concept in two different areas (Colldahl, Frey & Kelemen, 2013). This is what this thesis is planning to do, with an added twist of having comparison between Dubai and Singapore, with two Nordic regions Helsinki and Copenhagen. It will find out how smart cities are implemented in different areas and what solutions they are offering. Therefore, the purpose of this thesis is to find an answer to the question of:

> *How are smart cities today tackling the main challenges driven by increasing urbanisation and climate change?*

Additional sub questions the thesis aims to answer are:

1. How have these cities become the world leaders of smart cities?

2. What are the main topic areas that the chosen smart cities are prioritising as well as lacking at?
3. How do smart cities in the Nordic region and outside of Europe differ?

An aspect that makes the comparison interesting, is that Nordic countries are often seen as very innovative, sustainable and technologically developed (Active Sustainability, n.d.). This is seen, as in the Global Innovation Index ratings Sweden, Finland, Denmark and Norway are all ranked in the TOP 20, Denmark being in the sixth spot (Dutta, Lanvin & Wunsch-Vincent, 2020). Sustainability has also been a top priority to the Nordic countries, they are at the forefront of sustainability rankings and additionally they have a goal of being the leaders of international climate sustainability pledging to become the most sustainable region in the world by 2030 (Active Sustainability, n.d.). Additionally, the Digital Economy and Society Index of the EC has rated Finland and Denmark to be the first and third country leading on digital performance (European Commission, 2020). This makes it interesting to see, whether the smart cities in the Nordic region are also more advanced and more in line with the Giffinger smart city framework, than other SCs in high income countries.Technological advancement is also a priority for Singapore and UAE. Singapore was rated the second country for the Digital competitiveness ranking in 2020 and UAE was in the 14th place (IMD, 2020)

High-income countries were chosen for this thesis to have a more equal comparison between the smart cities. It would be interesting to include developing countries to the analysis, but it is expected that the problems and priorities there would be different than the ones in developed countries, making the analysis biased.

The research contributes to a small but growing area of literature by giving insight into which areas of the smart city concept the chosen cities are lacking and/or leading, what could be improved and what ideas are pioneering and could be adopted elsewhere. The goal is to find out how the smart cities today are tackling the urbanization issues and climate change as well as what the main areas are that differ between Nordic and non-Nordic smart cities. This can be used as a roadmap for different strategies of smart city implementation for countries cities aspiring to use that concept.

It is expected to find that the smart cities in the Nordic region have their main emphasis on human capital and environmental sustainability, whereas Singapore and Dubai focus more on

sustainable economic growth and high-tech solutions. Additionally, the author expects the cities to have a well-rounded approach to smart-cities based on the chosen framework, as they all belong to the TOP50 smart cities in the world.

1.3 Delimitations

The smart city concept covers many different fields and topics. This thesis will put its main efforts into focusing on the environmental sustainability, digitalisation and mobility aspects of the smart city concept. However, other characteristics of the SC will not be neglected and will still be included in the analysis.

Four cities were chosen to represent this analysis: Singapore, Dubai, Copenhagen and Helsinki. The first two represent high-income countries outside of Europe, and Copenhagen and Helsinki are an example of Nordic smart cities. These cases were chosen, as they represent two politically and geographically different areas, whilst at the same time being technologically advanced and high-income areas.

2 Literature Review

This part of the thesis will introduce the theoretical framework that the analysis of this research is based on. It will also give an overview of the cases that were chosen as well as a background of previous literature on the topic.

2.1 Theoretical Framework

The environmental sustainability side of smart cities aligns well with the theory and philosophical background of ecomodernism. According to Sagoff (2018), this is a train of thought that first started to gain traction in the early 2000s and it aims to find a solution to ecological issues during the Anthropocene with the help of technological advancement. He explains that according to ecomodernism, economic growth can continue whilst being decoupled from the use of natural resources. He expresses that ecomodernism was developed essentially as a response to environmentalism that is bound to the Malthusian pronouncements about planetary limitations and population growth being faster than the availability of resources, leading to increasing scarcity of resources and quality of life. The basic idea of ecomodernism fits well with the smart city concept, as both thrive for increased economic growth without sacrificing ecological or social well-being and find that technological innovation and development can be the answer to higher life quality without depletion of natural resources (Sagoff, 2018).

The Ecomodernist manifesto (Asafu-Adjaye, et al. 2015) argues that cities are the prime example of how the ecomodernism ideas can come to life. They find that high-income economies can start emphasizing sectors that are materially less intensive like service and knowledge sectors. The followers of ecomodernism ideas maintain that modern technologies are able to use resources more efficiently and reduce the human impact on the biosphere by embracing technological change. They argue that urbanisation could be seen as a positive process of allowing more space for nature and non-human species to thrive. An aspect, where

the ideas of SCs and ecomodernism do not quite match up is the production of energy. Smart cities are most often focused on renewable energy like solar, hydro and wind power, whereas ecomodernists argue that often these technologies are not power dense enough to cater for the growing population and for solar to be viable, it will require further innovation for cheap energy storage and scaling up. The authors of the manifesto find nuclear energy to be the most suitable for future use (Asafu-Adjaye, et al. 2015; Anttiroiko, 2015).

The theoretical framework used for the analysis derives from the work by Giffinger et al. (2007), who are one of the most cited authors in the smart city field (Dameri & Rosenthal-Sabroux, Smart City and Value Creation, 2014). The authors created a six characteristic framework that are following:

- Smart economy
- Smart people
- Smart governance
- Smart mobility
- Smart environment
- Smart living

Giffinger et al. (2007) state that the six characteristics have 31 more general factors and for better measurement ability the authors also came up with 74 indicators that were created keeping the smart city overall targets in mind. This framework was created to rate medium-sized cities in Europe, but as the main ideas were quite general at the characteristics and factors level, they are possible to apply to any smart city, regardless of location (Giffinger, et al. 2007).

Giffinger et al. (2007) explain that the smart economy relates to the economic competitiveness of the city. They express that the characteristic includes entrepreneurship and the ability to transform the urban area as well as productivity and flexibility of the labour market. The indicators also include aspects such as the governmental expenditure on research and development (R&D), innovation that is measured by patent applications, unemployment rates, and how many new businesses are registered in the area (Giffinger, et al. 2007).

Giffinger et al. (2007) continue that the smart people aspect does not only relate to the educational level of the citizens, but also the opportunities and quality of long-life learning, the level of participation in the public life and social interactions such as integration and open

mindedness toward cosmopolitan ideas. Smart people indicators include voter turnout and share of people working in creative industries (Giffinger, et al. 2007).

Moving on to the smart governance characteristic, Giffinger et al (2007) state that this characteristic also includes participation in decision-making, the quality and accessibility of public and social services as well as governance staying transparent. More specifically the authors explain that the characteristic involves the share of political representatives per resident as well as share of female political representatives in the city. Additionally, it explores the citizens satisfaction with transparency, schools, and corruption (Giffinger, et al. 2007).

Giffinger et al. (2007) specify that the smart mobility has mostly to do with the traffic, public transport as well as internet access. More specifically access to public transport and broadband as well as share of sustainable cars and other green ways of transportation (Giffinger, et al. 2007).

The characteristic of smart environment contains the factors of pollution, sustainable resource management as well as environmental protection; it measures use of water as well as electricity, efforts to protect the environment as well as the share of green space in city areas and summer smog (Giffinger, et al, 2007).

Giffinger et al. (2007) argue that the smart living characteristic includes the biggest number of factors and indicators. They say that it has to do with different health conditions such as life expectancy and access to health care as well as safety and crime rates. Additionally, the authors find that it involves housing quality and education facilities as well as tourism rates and social cohesion such as poverty rates.

Giffinger et al’s. (2007) model helps with finding out in which areas the cities are lacking, what the current state of the SCs are, and how it can improve to meet all conditions of a smart city. It gives a structured way of analysing each of the cases based on the characteristic, giving a holistic view of different implementations of smart cities in chosen areas.

2.2 Previous Research

The success of cities has for the longest time been seen as economic performance and income evaluations (UN-Habitat, 2020). The World Cities report (2020) claims that, with the rapid urbanisation, the evolution of manufacturing and technology, new issues have come to play a role in cities. The report argues that this is why nowadays the focus has shifted more towards environmental and economic sustainability, ICT services as well as human capital. There is an increasing demand for finding the right balance between economic growth, social welfare and sustainability and this is one of the main drivers for smart city implementations (Dameri & Rosenthal-Sabroux, Smart City and Value Creation, 2014).

According to Benevolo (2014) the smart city has roots in many different areas of study and throughout time the urban strategies have melded into the smart city vision of today. The author suggests that there are three mainstream topics, that have emerged in the literature: digital city, that focuses on ICT and creating an interconnected network for citizens, authorities and organisations; green city, which emphasizes environmental sustainability on urban spaces, reducing pollution and waste and calls for sustainable use of resources; and knowledge city which advocates for the importance of data collection and availability and production of knowledge and innovative thought. Smart city is therefore a mixture of all three (Benevolo, Dameri & D'Auria, 2014).

According to Dameri and Rosenthal-Sabroux (2014) smart city is essentially a collection on different projects and initiatives that are implemented by both public and private actors. The concept is seen as a winning strategy in urban development as it does not require sacrifices from the quality of life, but rather the goal is to improve it whilst at the same time implement environmentally sustainable solutions (Benevolo, Dameri & D'Auria, 2014)

2.2.1 Smart City Governance

An important step in smart city installation is the relationship between city governance and citizens (Giffinger, et al. 2007). More precisely, smart city governance puts major emphasis on participatory governance and allowing citizens to become an essential part of decision-making (Bennett, Pérez-Bustamante & Medrano, 2017). According to a research by Ruhlandt (2018)

there are several behavioural or procedural changes that are at the forefront of smart city governance, whereas the main changes occur within the areas of efficiency, innovation, transparency and citizen-centricity. Greater efficiency is important in several different areas of SC development, but in the context of governance authors have emphasised potential savings, such as time efficiency in decision-making processes (Ruhlandt, 2018).

Creating an innovative environment is another essential aspect of SCG. According to Lim Edelenbos and Gianoli (2019) innovation could be enabled through creating smart clusters or living labs. The authors find that increasing cooperation between different actors and stakeholders such as the government, community, urban specialists and the public sector play an integral role in facilitating innovation. The city governments need to be transparent with sharing their concepts and visions with the inhabitants (Ruhlandt, 2018).

Finally, citizen-centric cities are expected to serve their citizens within their needs and implement operations, based on expectations (Ruhlandt, 2018). According to Lim Edelenbos and Gianoli (2019) empowering citizens and allowing them to be a part of the decision-making is a crucial aspect of SC. Moreover, the authors suggest that providing job-training and life-long learning opportunities as well as job opportunities for marginalised people is seen as an integral part of SC development.

According to Guimaraes et al (2020) the main aspect of the governance in smart cities is the quality of life. They find that the base ideas of smart cities such as human and social capital, ICT infrastructure and economic development are also the basis of improved well-being and quality of life. Merli and Bonollo (2014) argue that another integral part of smart city governance is the existence of monitoring activities. They find that when the governing authorities have an external actor to respond to, it motivates them to involve the community and the stakeholders in developing services and activities, that are properly measurable and have clear functions.

2.2.2 Smart city Mobility

Mobility is an integral part of urban living. Getting from one place to another can and has become a strenuous activity on the environment, largely because of the associated transportation pollution (Mazur, 2020). Smart transportation is essentially a concept that uses

new innovative ideas and technologies to create more sustainable, convenient, and cost-effective ways of mobility (Mazur, 2020). Mobility is a tough topic for smart cities, as it involves both environmental sustainability and economy and finding the ways to balance out both and create innovative solutions that does not require sacrifices on either end (Benevolo, Dameri & D'Auria, 2014)

The transportation sector today is still largely dependent on fossil fuels According to Smart City Sweden. They find that smart city transportation solutions are also meant to tackle the problem of efficient mobility whilst lowering emissions. This includes public and shared transportation, distribution, and other green ways of transportation, such as bicycles (Smart City Sweden, Mobility, n.d). Menouar et al. (2017) argue that the technology for smart transportation systems is continuously improving. They note that connected and autonomous vehicles are tested out in many countries already, which will enable many new opportunities for services and applications of such vehicles. Another innovative aspect of mobility that has been gaining momentum is drones, which can be used for agriculture, security as well as delivering goods (Menouar, et al. 2017)

Dameri (2014) argues that to create incentives for choosing sustainable transportation options, cities should opt to developing their bike roads and schemes, make sure that there is available information on real time bus timetables, create systems for electric carpools and set up congestion charging spots (Dameri, 2014). According to Yan et al. (2020) traffic congestion is an issue that has many sides, it increases energy use and therefore pollution, but it also increases travel time and costs. They bring an example of China, where the traffic congestion is a main contributor to air pollution, as cars standing around and traffic not moving ultimately contributes to higher emissions. The classic measures like road widening and road rationing based on plate numbers are not long-term solutions, instead smart cities should focus on advancing and developing public transport accessibility and availability (Yan, Liu & Tseng, 2020).

Kumar and Dahiya (2017) indicate that for private and commercial mobility, main solutions include hybrid and electric vehicles as well as car-sharing. They argue that car sharing results in a lower amount of people needing private cars, as they are able to rent a car when necessary also creating incentives for more use of public transport and walking/biking. However, car-

sharing initiatives have been hard to implement in areas, where there is a strong societal importance in owning a private car (Kumar & Dahiya, 2017).

2.2.3 Smart City and Digitalisation

Digitalisation and technological advancement are one of the bases of implementing smart cities; digitalisation allows to help tackle problems such as increased demand for transportation and energy as well as create a positive social impact within the areas of education and health services (Smart City Sweden, Digitalisation, n.d.).

According to the World Cities Report (UN-Habitat, 2020) innovative technology can be a driver for economic growth, productivity and social inclusion, as long as the access to technology and services are available to the population in an inclusive way. The report claims, that otherwise, it can create a bigger digital divide in the urban areas resulting in increased inequality. There are many ways to digitalise different aspects of a city, such as "smartphone apps, city data dashboards, information screens in public spaces, intelligent operations centres and public-facing websites with critical information and feedback mechanisms." (UN-Habitat, 2020, p. 183). One of the main goals for the digitalisation in a smart city is to create a continual flow of data that is constantly updated and with the help of intelligent algorithms, it creates a better way to make decisions for the citizens (UN-Habitat, 2020).

According to Dameri and Rosenthal-Sabroux (2014) digitalisation is an important aspect of a smart city implementation and community development; however, the technological advancement must go hand in hand with investments in social capital and high involvement of citizens in the development process.

2.2.4 Smart City and Environmental Sustainability

According to Fontana (2014) the task of tackling the issues related to environmental sustainability falls mainly on the shoulders of the local authorities. He argues that the challenge comes from the place that the governing institute is expected to fulfil the growing needs of the citizens whilst at the same protecting the increasingly scarce public resources. The author continues, that this is made even more difficult by the rapidly growing needs of the public and deteriorating availability of sources and in addition, there are many different actors in play,

such as larger governmental actors, NGOs, citizens and corporations. This is where a lot of authorities turn to the answer of 'turning smart,' as it offers innovative urban solutions for sustainable socio-economic development (Fontana, 2014).

Urbanisation and environmental sustainability are often seen as clashing progresses, the former being a risk to achieving the latter (UN-Habitat, 2020). According to Shamsuzzoha et al. (2021) the main aims for smart cities concerning environmental sustainability is preserving increasingly scarce resources as well as reducing the emissions. The authors explain that this can be done in many ways such as improving energy efficiency, decreasing water consumption and creating effective waste systems and recycling processes. Sustainable development in the cities cannot however be achieved without the inclusion of citizens according to Solano et al. (2017).

> The concept of sustainability, the thrust of social responsibility, in the lives of people, leads them to think about future generations, which will result in the need to acquire capabilities and skills to increase the value of companies, cities and the society. To obtain them, a great effort must be made to educate citizens on sustainability (Solano, Casado & Ureba, 2017, p. 66).

2.3 Case selection

There were four cases chosen for this thesis to examine the Smart City approach in different environments. First two are Dubai and Singapore, and the second two are in the Nordic areas where Copenhagen and Helsinki were chosen.

These cases propose an interesting comparison, as the Nordic cities belong to a Nordic Smart City Network (NSCN), that is a collaborative initiative for smart city development that joins 5 countries and 20 cities in their efforts (NSCN, n.d.). According to NSCN, this collaboration allows the cities to share and learn from others' experiences, as they have similar values and goals, such as environmental sustainability, open data, and citizen-centric approach. As mentioned previously, Nordic countries are also known for thriving in sustainability and technological advancement, making them great cases to study regarding the smart city initiative (NSCN, n.d.).

Dubai a capital of one of the of seven emirates in United Arab Emirates, located in the Gulf region and has a population above 3 million people (Sabri, 2020). Emirates is an elective Islamic monarchy, composed of the seven autonomous emirates (Nations Online, n.d.). According to Crystal (2021) Dubai is "… one of the region's most vital commercial and financial centres, housing hundreds of multinational corporations in a forest of skyscrapers". Sabri (2020) argues that the population growth in Dubai is one of the fastest in the world, making them prone to problems related to overpopulation. United Arab Emirates has started their journey towards implementing an e-governance system since the early 2000s (Badran, Smart-Governments for Smart Cities: The Case of Dubai Smart-Government, 2019). They are currently one of the world leaders in providing governmental services through e-gates and are working on continuously improving smart-government initiatives and technologies to solve problems regarding the public service design (Badran, Smart-Governments for Smart Cities: The Case of Dubai Smart-Government, 2019). The majority of the country's population lives in the urban areas, mainly Abu Dhabi, Dubai and Sharjah, where population growth has been eminent and therefore the need for electricity and water and food has increased greatly (Alzaabi, Rizk & Mezher, 2019). The smart city Dubai initiative has put its main efforts into focusing on increasing the quality of life and happiness of the citizens as well as achieving financial savings (Geray, 2019).

The Singapore city-state is a global financial centre and one of the most densely populated areas in the world with 5,7 million citizens (World Bank, Population, total - Singapore, 2019). It is a small island with no particular natural resources (Lim, Rajabifard, Khoo, Sabri & Chen, 2020). According to the UN (1997) already since the 1980s, Singapore has been concerned for the protection of the environment, which is when the basis was laid by building the institutions and infrastructure necessary to enjoy a clean and healthy environment. The country has initiated the Singapore Green Plan (SGP) which is an environmental plan by the government regarding policies and goals that would end up transforming it to a Green City (UN, Implementation of Agenda 21: Review of Progress Made since the United Nations Conference of Environment and Development, 1992, 1997). As for their smart nation, Singapore aspires to make the city a leading economy complemented by digital innovation and a world-class government (Smart Nation Singapore, n.d.).

Denmark is a Scandinavian country located on the Jutland Peninsula (Nokkentved, 2021). It has 5,8 million inhabitants of whom 1,36 million live in Copenhagen (World Bank, Population,

total - Denmark, 2019; World Population Review, Copenhagen Population 2021, 2021). According to Nokkentved (2021) Denmark is considered to be quite a small country with a small population amongst the European countries. They note that it has highly developed social services and quality of life, as the public spending is directed toward health, social services, education, etc. They state that the economy is focused mainly in areas like service industries, trade and manufacturing. Since the beginning of the century, the country has been steadily moving towards renewable energy as well, as building additional coal power plants was banned and wind farms were subsidised (Nokkentved, 2021). The capital of Denmark is implementing many smart city projects and has set ambitious goals for becoming the world's first carbon-neutral capital by 2025, and completely independent of fossil fuels by 2050 (Copenhagen Capacity, n.d.). Copenhagen has become a place for testing out new technologies and becoming an early adopter of new smart city solutions like cleantech and integrated data exchange (Copenhagen Capacity, n.d.).

Finally, Finland is the second chosen Nordic country with 5,5 million inhabitants 1,3 million of whom live in Helsinki (World Bank, Population, total - Finland, 2019; World Population Review, Helsinki Population 2021, 2021). According to Henriksson (2021) it is one of the most remote and Northern countries in the world and experiences severe climate. He states that Finland relies heavily on its most abundant natural resource, which is wood. Three quarters of the land is covered in forest and one fifth of the national consumed energy comes from wood, however the national government has programs in place to prevent forest depletion (Henriksson, 2021). The Helsinki smart city region includes the Helsinki-Uusimaa region, which is a mix of city and countryside, bringing together actors and stakeholders from both areas (Helsinki Smart Region, n.d.). The smart region includes three main topics: the citizen's city which emphasizes user-friendly services and solutions, the climate neutrality, which is a goal to transition to low-carbon society and become carbon neutral by 2035, and finally the industrial modernisation, that includes developing leading technologies as well as providing incentives for innovation activity (Helsinki Smart Region, n.d.)

3 Methodology

In this part of the research, the design, data collection and analysis methodology for the research will be discussed and motivated. It summarises which methods will be used on the chosen data to be able to provide the answer to the research question.

3.1 Research Design

Qualitative research was chosen for this thesis, as the analysis will mainly include examining textual materials, such as academic articles and reports by national and international organisations (Bryman, 2012). According to Miles and Huberman (1994) qualitative research should be chosen when "most analysis is done with words, that can be assembled, subclustered, broken into semiotic segments. They can be organized to permit the researcher to contrast, compare, analyse, and bestow patterns upon them" (Miles & Huberman, 1994, p. 7).

This research will be using comparative design. According to Bryman (2012) comparative design is used to compare two different cases using similar methods. In this case the two comparative cases are Nordic and non-Nordic smart cities, two examples from each.

Qualitative comparative analysis is used for both academic as well as evaluation purposes. According to Pattyn, Molenvald and Befani (2017) this design allows to gather in-depth information of different cases whilst being able to capture their complex nature. "By systematically comparing cases as configurations of conditions and outcomes, evaluators can search for prevalent patterns and identify redundant conditions or conditions that do not seem to make any difference to explain a certain phenomenon" (Pattyn, Molenveld & Befani, 2017). According to Lijphart (1971) comparative design suits best with a study that deals with a small number of cases, which makes it suitable for this thesis, as 4 cases are considered.

3.2 Data Collection Method

The data collected for this research has been gathered from several different sources. The thesis relies on secondary sources, meaning that the author itself was not responsible for gathering the data from the main source but relying on other researchers' collected data (Bryman, 2012; Creswell, 2014).

Academic articles for the thesis have been collected through a key word search on LUBsearch and Google Scholar to find case studies about the selected countries as well as background research. Additionally, independent reports and conference proceedings by various organisations were found through google search using key words such as "smart city," "smart cities in Europe," "smart city Singapore," etc.

The cases were chosen with the initial idea of comparing smart cities in very different areas, therefore countries were chosen that were both in and outside of Europe. Through further research, more specifically the Nordic area was chosen, based on their innovation scores and technological advancement. Another reason these cases were chosen was because of availability of data. Smart cities are quite a new phenomenon and the literature that is available on certain cases is quite limited. Therefore, the four countries were chosen, as it was determined, that there are enough available book sections, articles and reports available to carry out the analysis.

3.3 Data Analysis

To analyse the specific cases chosen for this study a thematic analysis (TA) will be performed. According to Bryman (2012, p. 558) thematic analysis "is a common approach to analysing documents … and that it can be applied in relation to different kinds of orientation to qualitative data." TA offers the author a possibility to look into patterns across a large data set and helps to make sense of the shared commonalities of the entire theme (Braun & Clarke, 2012).

The basis of a thematic analysis according to Bryman (2012) is a framework, which is helpful by ordering and synthesising the data. In this case the framework is provided by Giffinger et al.

(2007) where the six characteristics of a smart city provide a perfect framework for this type of analysis.

In order to implement the thematic analysis, cross-sectional indexing will be used to match up existing data with the six characteristics of the theoretical framework. According to Mason (2002) indexing data in that way is beneficial, when the data is predominantly text-based, it helps to get a systematic overview of the data as well as finding themes and topics that do not appear in an orderly manner in data.

There will be two levels of indexing process for the analysis: the broader one will code pieces of data based on in which category they fit the best into, based on the Giffinger et al. (2007) framework. As mentioned previously, there are six characteristics of a smart city used for this thesis, which are: smart economy, smart people, smart governance, smart mobility, smart environment and smart living (Giffinger, et al. 2007). The second layer of coding will be the first step and more case-specific, finding country-specific insight and knowledge about each category, that would be relevant to the research questions. The indexing process will take place throughout the analysis, providing the research with categorised pieces of organised data, giving insight to all the different cases and their implementation of smart cities. The process is visualised on figure 1.

To gain assistance for this qualitative research a computer aided qualitative data analysis will be used (CAQDAS). The software that will be used is the ATLAS, which helps facilitate the indexing and knowledge retrieval process, as well as grouping certain codes together (Mason, 2002).

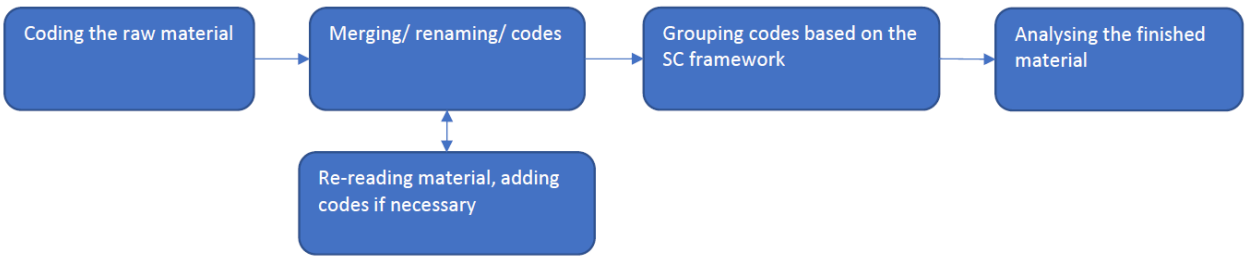

Figure 1: Data Analysis Process

3.4 Validity and Reliability

To ensure validity in this thesis, strategies suggested by Creswell (2014) were employed. He argues that it is important that data sources are triangulated, meaning gathering information from several different sources for establishing themes for the research. Additionally, the author emphasises on using a rich description for the findings to give the reader in-depth description of the setting. Both of these strategies were employed for this thesis.

Reliability is confirmed by using the same type of framework for smart city analysis that has been done by other authors in the past (Dameri & Rosenthal-Sabroux, Smart City and Value Creation, 2014).

3.5 Limitations

As with every research, there are limitations to this thesis, that are essential to highlight. First of all, no original data was collected for this study and only secondary data was used. This means that the author was fully dependent on data that was gathered by other researchers and published online. There are limitations to basing an analysis on secondary data, such as the lack of control over the quality of data as well as absence of some information that is either not accessible or not published (Bryman, 2012). However, using secondary data has allowed this research to examine a far larger dataset than it would be by collecting it first-hand and the quality of data is assumed by the author, based on the chosen sources.

Another aspect that limits this research is that smart cities are still mostly a work in progress in many cases, where there is information available on a lot of goals and aims for future project and ideas, however their evaluation is not yet seen. Therefore, for the analysis, this was carefully taken into consideration to not include cities' goals into the analysis, as they essentially have no value without the provision of evaluation. Finally, the entire data collection was done in English, which means that the possibly available sources that were in other languages, were not considered.

4 Empirical analysis

The following chapters include the analysis of the four chosen cases of smart city implementation in Helsinki, Copenhagen, Dubai, and Singapore. All the cases are analysed through the Giffinger et al. (2007) SC framework. The codes visible in the tables for each case are often multifaceted, therefore one code could be possible to place in different sections, as often they represent cooperating activities between different actors. However, they were placed upon the judgement of the author and are further examined and explained in the analysis.

The text includes small parenthesis with notes, suggesting which type of characteristic and code it is referring to, e.g. SM3 would be the third code in the smart mobility characteristic, SP2, second code in smart people characteristic. There is an illustrative table in the end of all sections showing all codes and under which characteristic they belong to.

4.1 Singapore

Singapore presents an interesting case as unlike others, it is a smart city-nation, which means that the smart Nation concept is centrally managed by the government (Cavada, Tight & Rogers, 2019). Singapore has been focused on becoming a leader in technological advancement and digitalisation for decades (Mahizhnan, 1999) and in 2014 the smart nation initiative was launched (Johnston, 2019).

The smart mobility characteristic includes the most codes in this section. The nation has prioritised sharing open data in order to incentivise innovation activities and business creation (Cavada, Tight & Rogers, 2019; Chang & Das, 2020; Hoe, 2016) (SM3). According to Cavada, Tight and Rogers (2019) the government finds that technology is the main factor enhancing liveability and therefore has emphasised the digital connection between the government and the citizens (SM3). The open data shared includes live images of traffic, the availability of taxis,

cycling paths across the nation, and the occupancy levels of bus stops (Chang & Das, 2020, p. 431) (SM3). This type of data availability creates efficiency and convenience in citizens everyday lives. A more specific measure in that area is The Moments of Life Initiative that is a platform designed to use governmental services digitally, like registering a birth, getting information on health insurances or benefits as well as senior active aging programmes (Johnston, 2019) (SM4). The open data availability also encourages co-creating solutions for businesses, as they are better able to find problem areas (Hoe, 2016) (SM3).

The local infrastructure is another well-developed aspect in Singapore. The government has developed a national information infrastructure, a good broadband connection (Mahizhnan, 1999) (SM1) as well as well- planned public transport networks in high-density areas (Ng & Kim, 2020) (SM5). Additionally, there is a wide network of sensors collecting data in real-time, providing information on different urban data, such as air quality, traffic, peoples' movements as well as energy and water usage (Johnston, 2019) (SM2) Moreover, the city is implementing projects for autonomous transport opportunities, like minibus or shuttle services (Cavada, Tight & Rogers, 2019; Shamsuzzoha, Nieminen, Piya & Rutledge, 2021) (SM7). According to Lim et al. (2020) the current infrastructure is even further developed by a 3D national topographic map that assists different agencies in urban development planning, policy making and risk management. The authors find that this has also an impact on receiving information on environmental challenges, such as walkability analysis, flood information, thermal comfort of outdoor spaces, etc (SM6). This is also connected to the smart flood control system, that included cleaning up the local rivers and with a network of sensors, the system uses drainage pumps and crest crates for dealing with either draughts, storms or rainfall (Johnston, 2019) (SEn5).

For the smart governance characteristic, there are many initiatives implemented by the nation, as it is the main driving force toward smart city initiatives. Most of the governmental services have moved to a digital platform, creating easy access to the citizens that has been argued to be inclusive in a sense of all people having access, which is also simplified by the MyInfo platform that stores personal information for auto-form filling (Cavada, Tight & Rogers, 2019; Johnston, 2019; Chang & Das, 2020) (SG1,2). There is also a feedback app that has been created for citizens to rate their living quality in different areas, giving the government a possibility to rapidly find solutions (Cavada, Tight & Rogers, 2019) (SG2). Cavada, Tight and Rogers (2019) argue that the fact that Singapore is governed by a central administration gives it an advantage,

enabling faster processing of smart initiatives than it could be for others with local administrations that have to work within national guidelines (SG4).

The government also avidly supports innovation initiatives, scientific advancement and business collaborations as well as youth development projects, e.g. providing "research grants, national collaborations and logistical platforms, public services developments, and digital tools for innovative development" (Cavada, Tight & Rogers, 2019, p. 302) as well as awards for youth leadership, grants for youth research and volunteering projects and opportunities (Cavada, Tight & Rogers, 2019) (SG3,5,6).

For smart environment, there are some systems in place, but there is also critique that it is not prioritised enough on the agenda (Cavada, Tight & Rogers, 2019) (SEn3). As energy consumption creates high pollution, the government has opted for some solutions regarding efficiency. Bhati, et al. (2017) bring an example, that as the most energy invasive appliances having mandatory energy labelling containing efficiency ratings as well as home energy management systems that help homeowners track their consumption (SEn1). They authors add that, the government is also trying to nudge people to recycle more by providing proper recycling areas closer to people's homes (SEn4). The government is constantly gathering information on the local environmental impacts by firstly using an app, where citizens give feedback on environmental issues as well as through microclimate systems, that show where the most heat-producing areas are (Cavada, Tight & Rogers, 2019) (SEn6). Singapore has also been fighting the unnecessary car usage in the city by putting many restrictions and taxes in place, two thirds of car purchases are taxed and, there are high registration fees, additionally there are high taxes on fuel and high parking fees as well as road pricing (Ng & Kim, 2020) (SEn2).

For smart living, Johnston (2019) argues that Singapore is one of the safest cities in the world, that comes down to the availability of having around 15 cameras per 1000 people all around the city for surveillance (SL2). Under the same characteristic are the smart home tools for monitoring the elderly, keeping their caregivers updated on their safety (Chang & Das, 2020) (SL2).

The smart people characteristic includes the government's focus on furthering education, especially in the field of IT. Singapore has been emphasizing technological knowledge since

the 1990s, contributing to "Singapore being one of the first countries to achieve an advanced, nationwide IT structure" (Chang & Das, 2020, p. 431; Mahizhnan, 1999) (SP2). Additionally, the government offers different digital training programs and fellowships (Cavada, Tight & Rogers, 2019) (SP1).

Smart economy is largely compatible with the digitalisation process. Singapore emphasizes creating opportunities for co-creating between citizens and businesses and it is expected for the digitalisation to exceed 4,6 trillion US dollars within a decade (Lim, Rajabifard, Khoo, Sabri & Chen, 2020; Cavada, Tight & Rogers, 2019) (SEc1-3). Technoparks are another thing that create a large economic impact attracting a lot of foreign interest and direct investment (Chang & Das, 2020) (SEc3). Additionally, the Singapore Agency for Science, Technology and research is highly invested in providing funds for economically oriented scientific research (Chang & Das, 2020) (SEc4).

Table 1: Smart City Singapore Analysis

smart mobility	**smart governance**	**smart environment**
telecommunication and IT infrastructure (Mahizhnan, 1999) SM1	inclusive digital access (Johnston, 2019) SG1	efficient energy management system (Bhati, Hansen & Chan, 2017) SEn1
sensors collecting urban data (Johnston, 2019) SM2	digitalisation providing efficient government services (Cavada, Tight & Rogers, 2019; Johnston, 2019; Chang & Das, 2020) SG2	promoting car-free agenda (Cavada, Tight & Rogers, 2019; Ng & Kim, 2020; Chang & Das, 2020) SEn2
open data supporting business creation and innovation (Cavada, Tight & Rogers, 2019; Chang & Das, 2020; Hoe, 2016) SM3	government supporting youth by facilitating projects and opportunities (Cavada, Tight & Rogers, 2019) SG3	smart agenda not prioritising environmental benefits (Cavada, Tight & Rogers, 2019) SEn3
The Moments of Life Initiative (Johnston, 2019) SM4	advantages of central administration (Cavada, Tight & Rogers, 2019) SG4	convenient recycling system (Bhati, Hansen & Chan, 2017) SEn4
technologies to aid citizen access to public transportation (Cavada, Tight & Rogers, 2019; Johnston, 2019; Ng & Kim, 2020) SM5	government supporting innovative initiatives (Cavada, Tight & Rogers, 2019) SG5	smart flood control system (Johnston, 2019) SEn5
3D mapping of the city (Lim, Rajabifard, Khoo, Sabri & Chen, 2020) SM6	government funding scientific advancement and business collaborations (Cavada, Tight & Rogers, 2019; Johnston,	studying urban area for environmental developments (Cavada, Tight & Rogers, 2019; Lim et al. 2020) SEn6

	2019; Chang & Das, 2020) SG6	
autonomous transportation (Cavada, Tight & Rogers, 2019; Shamsuzzoha, Nieminen, Piya & Rutledge, 2021) SM7		
smart living	**smart people**	**smart economy**
elderly monitoring system (Chang & Das, 2020) SL1	digital training programs and fellowships (Cavada, Tight & Rogers, 2019; Lim, Rajabifard, Khoo, Sabri & Chen, 2020) SP1	priority to innovative digital solutions and economy (Cavada, Tight & Rogers, 2019; Lim et al 2020) SEc1
surveillance and cameras leading to safe city space (Johnston, 2019) SL2	emphasizing IT education (Mahizhnan, 1999; Chang & Das, 2020; Hoe, 2016) SP2	co-creation and cooperation between stakeholders (Lim et al. 2020) SEc2
		digitalisation providing fiscal benefits (Cavada, Tight & Rogers, 2019) SEc3
		economically oriented scientific research (Chang & Das, 2020) SEc4

4.2 Dubai

Smart Dubai is a project that was started in 2017, having 4 different milestones aimed to achieve by 2021 (Sabri, 2020). Dubai has set one big goal to achieve with different smart city projects, which is to develop Dubai to become the world's happiest city in the world (Zakzak, 2019) (SL4).

The smart mobility aspect includes several codes that represent the city's efforts digitalising the public system. They have put a lot of emphasis into establishing cooperation between companies, the authority and citizens and using artificial intelligence (AI) systems to make it more efficient (Sabri, 2020) (SM5). The agency that is running the process is the Ministry for Artificial Intelligence ensuring the "deployment of the latest technologies and tools of AI in government services" (Mohasses, 2019, p. 113) (SM1,5). AI is also used as an efficient tool for measuring the impact of implemented projects, it helps to analyse the users' feedback whilst using machine learning measure techniques to gain insight into the happiness and psychological

measures as well as determining future endeavours (Zakzak, 2019) (SM9). Another tool that is used for digitalising and optimising the governmental processes is blockchain. This decreases the time under which bureaucratic processes occur and also reduces the necessary labour costs, as they become automated (Breslow, 2021) (SM6). Moreover, a smart prosecution system was also implemented in Dubai for better access to legal frameworks as well as access to legal applications for lawyers without having to attend headquarters in person (Badran, Smart-Governments for Smart Cities: The Case of Dubai Smart-Government, 2019) (SM3). To be able to take advantage of the new technological opportunities, Smart Dubai has sought to create formal and informal education opportunities, to have the knowledge to make the new strategies work efficiently (Zakzak, 2019)(SP1).

Based on the analysis, it was found, that Dubai puts a lot of the effort toward digitalising the public sector, creating solutions for the citizens to access public services better and creating feedback systems that give insight into citizens' needs (Sabri, 2020; Zakzak, 2019) (SG1,2,5). However, a criticism that occurred was that the government could also work on creating the open data system, driving innovation, and improving governmental transparency (Mohasses, 2019) (SM2). The government highlights the importance of feedback and data regarding citizens' well-being by implementing studies measuring people's values and their contentment with life in the city regarding education, housing, and health, etc. (Zakzak, 2019) (SG1). The government is also working on providing an efficient digital infrastructure network in people's everyday lives, with the help of partnerships with many high-profile vendors to encourage innovation and fiscal benefits in the city (Sabri, 2020) (SG4, SEc1).

The city has also set up a virtual identification platforms like MyID and the UAE Pass to access governmental services easier (SM6). It allows the users to safely identify themselves for procedures like for example signing rental documents or registering utilities (Badran, 2019; Breslow, 2021) (SM6). This is complemented by the online payment system Mpay, which has been integrated into services of all the governmental websites (Badran, 2019) (SM8).

The smart living characteristic includes several aspects, however the main emphasis is put on the drive towards creating the happiest city on earth (Geray, 2019; Sabri, 2020)(SL4). This program is facilitated by "embracing technology innovation—making Dubai the most efficient, seamless, safe and impactful experience for residents and visitors" (A. Al-Azzawi, 2019, p. 198) (SL4) (SM7). The government has created a clear measuring system called the Happiness

Meter, which takes in feedback from mobile and desktop applications, which "allows the measurement and monitoring of people's level of satisfaction within industry sectors by geographic areas" (Sabri, 2020, p. 189) (SG5).

According to Brelow (2021) Dubai has also set up smart surveillance systems through the use of smart phones, as they have around 96% market penetration in UAE. Smart phones together with the EID[1] create a surveillance system of the residents as they move throughout the multicentric city (Breslow, 2021) (SM4). However, the author also criticises this to be invasive of peoples' private lives (SL2). The author continues that the surveillance aspect is further tackled by the use of sensors and cameras for the safety of the citizens, there are cameras throughout the city equipped with AI systems, which has been helpful for the city to capture individuals wanted for crimes (SL1).

For the smart environment aspect, the city has not made a lot of effort as of yet (Hozaim & Vishwesh, 2017) (SEn3). There are a couple of projects that are involved in this area, first of which is the implementation of the government going paperless and moving all documents online: "By eliminating the 1 billion pieces of paper used by the government each year, we could … prevent 130,000 trees from being cut down, and save 40 hours of productivity" (Smart Dubai, 2020) (SEn1). Another system that is in place is a smart toll system for roads, which helps with road congestion and discourages unnecessary travelling by car (Akre & Yankova, 2019; Mohasses, 2019) (SEn2). Finally, there is also movement towards solar panel adoption, where the Shams Dubai project allows the residents to "to install solar photovoltaic panels and generate their own energy (SEn4). The power generated in each building can be connected to the city's power distribution network (DEWA) and an incentive returns to the customers, who contribute to the network out of the surplus consumption" (Sabri, 2020, p. 188) (SEn4). However, it can be seen, that the environmental sustainability has not been made a priority by Dubai.

[1] a biometric card incorporating both a smart chip and an RFID chip that is proof of one's legal residency in the UAE and which all residents are legally required to have in their possession at all times (Government of the United Arab Emirates, 2019 in Breslow 2021).

Table 2: Smart City Dubai Analysis

smart mobility	**smart governance**	**smart environment**
establishing ministry for artificial intelligence (Mohasses, 2019) SM1	feedback systems to ensure positive transformation (Zakzak, 2019) SG1	going paperless in the government (Smart Dubai, 2020) SEn1
no open data system (Mohasses, 2019) SM2	integrating the digital economy in policy making (Sabri, 2020) SG2	smart toll system for roads (Akre & Yankova, 2019) SEn2
smart prosecution system (Badran, 2019) SM3	studies implemented to find out citizens wants and needs regarding the city (Zakzak, 2019) SG3	criticism towards lack of environmental actions (Hozaim & Vishwesh, 2017) SEn3
smart surveillance systems through smartphones (Breslow, 2021) SM4	government as a key actor in technological and social innovation (Sabri, 2020) SG4	allowing citizens to install solar panels (Sabri, 2020) SEn4
using AI as a product or service in cooperation between public and private sector (Sabri, 2020) SM5	citizen-centric system (Badran, 2019; Zakzak, 2019) SG5	
virtual identification platform for digitalised governmental services (Badran, 2019; Breslow, 2021) SM6		
happiness through technology (Sabri, 2020) SM7		
online payment services (Badran, 2019) SM8		
using AI to measure project effects (Zakzak, 2019) SM9		
smart living	**smart people**	**smart economy**
sensors and cameras for citizens' safety (Breslow, 2021) SL1	creating education opportunities (Zakzak, 2019) SP2	governmental partnership with high profile technological vendors (Sabri, 2020) SEc1
invasiveness of people's lives (Breslow, 2021) SL2		
“happiest city on earth,” (A. Al-Azzawi, 2019; Sabri, 2020) SL4		

4.3 Helsinki

To analyse the Helsinki smart city based on the chosen framework, 6 sources were used. They consisted of 4 academic articles and two conference papers.

The Helsinki smart region consists of two separate areas, the city itself and the countryside of Helsinki-Uusimaa. The region provides around one third of all jobs in Finland and has been transformed into a dynamic knowledge and innovation hub (Smart Helsinki Region, n.d.).

There are many aspects that the Helsinki smart region has been working on regarding the smart mobility aspect of smart cities. The city has put a lot of emphasis on providing open data for no cost to the citizens and companies to create a free knowledge base about the processes and developments of the city as well as incentivise developers to utilise the data as relevant value for applications and "supporting services that create value for citizens and private or public actors" (Boes, Buhalis & Inversini, 2015; Hielkema & Hongisto, 2012) (SM7). Additionally, access to open data helps facilitate collaboration opportunities, implementing demand and user-driven innovation, as well as citizens' trust toward the city officials (Martikka, et al. 2018; Boes, Buhalis & Inversini, 2015) (SM7; SG3; SEc1).

According to Hielkema and Hongisto (2012), another big project for the city is the Forum Virium which is a living lab created in 2005 and owned by the local municipality; it brings together many different actors, such as companies, the government, citizens as well as the university and provides a co-creating space and network to develop new urban features (Forum Virium Helsinki, n.d.) (SM2,4). The authors argue that the living lab has been instrumental in helping the city implement its innovation policies. For example, this living lab facilitates the access to the open data and organises competitions for developers to take advantage of the data by creating apps and online services for the public use (Hielkema & Hongisto, 2012) (SM4,6). All of this is complemented by the smart people characteristic, more specifically Helsinki having a large skilled workforce, especially in mobile and future internet technology (Hielkema & Hongisto, 2012) (SP1). Additionally, the living labs are a great way to attract more people (nationally and internationally) to the area for learning and knowledge transfer (Boes, Buhalis & Inversini, 2015) (SP2).

The local governing organs are also very integrated into raising the social capital providing education for SC development, as they

> "organize forums, conferences, workshops, learning programmes and meetings dealing with smart city development in order to: collect ideas, comments and feedback about the cities' ICT requirements; generate interest; inform the community; engage new stakeholders and make the collaborative ecosystem larger; raise public awareness of the potential beneffts that ICTs can produce in urban environments; increase digital literacy; and stimulate collaboration" (Mora, Deakin & Reid, 2019, p. 78) (SP3)

The city has also implemented e-bike charging stations and mobile tickets for public transportation to create incentives for more use of public and green transportation (Martikka, et al. 2018; Hielkema & Hongisto, 2012) (SM1,3)

For the smart governance, the main emphasis for Helsinki has been on citizen-centricity, the bottom-up approach as well as public participation in decision making and governmental transparency (Laitinen, Piazza & Stenvall, 2017; Boes, Buhalis & Inversini, 2015; Martikka, et al. 2018) (SG1,2,3). The city is the main agency creating the framework for SC implementation (Mora, Deakin & Reid, 2019) (SG4). The city relies heavily on the citizen's feedback on implemented projects, to further increase the quality of life (Martikka, et al. 2018) (SG5).

Two main ideas were found for the smart environment concept, which are intelligent heating control and solar panel renting systems (Martikka, et al. 2018). The former is a pilot project implemented in two areas in Helsinki, where a smart thermostat adjusts the temperature for the residents and it can be seen that it helped the heating consumption to drop around 10% (Martikka, et al. 2018). According to Martikka et al. (2018) (SEn1). The PV renting system is facilitated by a company called Helen, it was created, as many people in the centrum do not have the possibility to put a solar panel on the roof of their house, as they live in apartment buildings. The author explains that the Helen system allows citizens to rent out a solar panel from a large solar plant and the energy produced is compensated in the customer's energy bill (SEn2).

Only one suitable urban solution was found for the smart living characteristic, which are the governmental efforts to use ICTs to assist the elderly citizens in their everyday lives (Mora, Deakin & Reid, 2019) (SL1).

When it comes to economic aspects, incentivising innovative solutions and cooperation between stakeholders were the most emphasised in the literature about Helsinki. The aspects related to economical growth are largely related to the mobility and ICT section earlier, as for example the collaborations facilitated by the Living Lab (Boes, Buhalis & Inversini, 2015) (SEc2,4). Moreover, the Mobile Application Cluster of Helsinki promotes various innovation competitions (SEc3,5), which drive "… competitiveness within the cluster and results in highly innovative ideas through a competitive community which is simultaneously attracting new firms to the area" (Boes, Buhalis & Inversini, 2015, p. 397) (SEc5).

Table 3: Smart City Helsinki Analysis

smart mobility	**smart governance**	**smart environment**
mobile ticketing for public transportation (Hielkema & Hongisto, 2012) SM1	citizen-centricity for planning (Laitinen, Piazza & Stenvall, 2017; Boes, Buhalis & Inversini, 2015; Martikka, et al. 2018) SG1	intelligent heating control (Martikka, et al. 2018) SEn1
diversified local IT cluster (Hielkema & Hongisto, 2012) SM2	bottom-up approach (Boes, Buhalis & Inversini, 2015) SG2	possibilities to rent a PV panel outside the city (Martikka, et al. 2018) SEn2
e-bike charging stations (Martikka, et al. 2018) SM3	transparent governance (Boes, Buhalis & Inversini, 2015) SG3	
living labs implementing innovation (Hielkema & Hongisto, 2012) SM4	city government providing a framework for SC implementation (Mora, Deakin & Reid, 2019) SG4	
mobile banking (Hielkema & Hongisto, 2012) SM5	public participation in decision making (Martikka, et al. 2018) SG5	
city mobile app for feedback collection (Martikka, et al. 2018; Mora, Deakin & Reid, 2019) SM6	government improving mobile technology services through Demand and User-driven Innovation Policy (Hielkema & Hongisto, 2012) SG6	
open data (Boes, Buhalis & Inversini, 2015; Hielkema & Hongisto, 2012; Martikka, et al. 2018) SM7		

smart living	smart people	smart economy
ICT solutions for elderly (Mora, Deakin & Reid, 2019) SL1	large skilled workforce (Hielkema & Hongisto, 2012) SP1	Creating demand and user-driven innovation (Hielkema & Hongisto, 2012; Boes, Buhalis & Inversini, 2015) SEc1
	attracting creative people (Boes, Buhalis & Inversini, 2015) SP2	cooperation between stakeholders prioritised (Laitinen, Piazza & Stenvall, 2017; Boes, Buhalis & Inversini, 2015; Hielkema & Hongisto, 2012; Mora, Deakin & Reid, 2019) SEc2
	providing education for SC development (Mora, Deakin & Reid, 2019) SP3	innovation competitions (Boes, Buhalis & Inversini, 2015; Hielkema & Hongisto, 2012) SEc3
		creating a platform for collaborative projects (Hielkema & Hongisto, 2012) SEc4
		competition creating drive (Hielkema & Hongisto, 2012) SEc5
		governmental innovation system initiatives (Hielkema & Hongisto, 2012) SEc6

4.4 Copenhagen

For smart mobility Alizadeh (2021) argues that Copenhagen emphasizes on the data flow in real time, such as peoples' movements, car flow, transportation, etc., giving more opportunity to deliver more effective and digitalised public services (SM3,4,5). The authors continue that the city finds it important to do it in a way that old infrastructure can be connected to the smart grid making it more cost-effective (SM4). Additionally, "(g)reater Copenhagen has become a preferred living lab for testing and developing smart city technologies, owing to easy collaboration with academia, the public sector and industry" (Copenhagen Capacity, n.d.) (SM2). However, Camponeschi (2021) has criticised the concept in Copenhagen as

marginalised people should be more included in the development, as for now, with the city advancing, it does improve living standards but also makes the areas more expensive to live in, thus leading to marginalised population having to move (SL1).

For smart governance the city is supporting innovation through policies, research grants and university funding (LSECities, 2014) (SG2, SEc1,2). There is also a strong feedback system for the government, where citizens are able to use an app to let the government know whether something needs to be changed or fixed (Bjørner, 2021) (SG1). However, they have been criticised for not taking citizen's input into account and having too much of a top-down way of governance (Camponeschi, 2021) (SG3).

Smart environment is something that plays a big role in the Copenhagen smart city agenda. There are many targets in place for reducing emissions, many of which have been achieved, like the 2015 target to reduce emissions by 20% compared to the ones in 2005 (Damsø, Kjær & Christensen, 2017) (SEn3). This is largely because of the reduced use of coal for heat and power plants and a shift towards renewable energy, which is highly incentivised by the government using subsidies, feed-in tariffs and conditions for cities to make space available for wind turbines (Damsø, Kjær & Christensen, 2017; LSECities, 2014) (SEn1,3). Even though, the economy of Copenhagen is growing, the energy consumption is not, as the systems implemented are more efficient than ever with the help of e.g. reusing waste heat (LSECities, 2014) (SEn5). Additionally, the city highlights the necessity for green areas in Copenhagen by creating an integral urban green space management strategy for parks inside the city as well as urban areas close to nature that are green areas close to or surrounding the city and have "greater potential for high levels of biodiversity which can be improved through interventions such as fauna passages and developing green corridors" (LSECities, 2014, p. 80) (SEn7).

Smart environment characteristic includes also efficient waste management, where with the help of sensors it is possible to identify where garbage cans are filled up and need to be emptied, therefore decreasing the need for garbage trucks to drive everywhere (Bjørner, 2021) (SEn4). Additionally, only 2% of Copenhagen's waste goes to landfill, most of it is recycled or incinerated (LSECities, 2014) (SEn4).

The city of Copenhagen is also extremely focused on offering a good network of public transportation, as well as bike roads, to ensure more people using those rather than driving a

car (SEn2, SM6). There are also taxes on transport fuels, that further incentivise people to use alternative modes of transport (LSECities, 2014) (SEn6). Because of well-designed urban planning, like safe roads and special traffic lights for bikes, nowadays there is a large population in Copenhagen that use bicycles as their main mode of transport (Damsø, Kjær & Christensen, 2017; Alaverdyan, Kucera & Horák, 2018) (SEn2). The city has also found a way to use cyclist to collect anonymous data about the city environment through: "…a project called The Copenhagen Wheel. This allows bicycles to become Smart by equipping them with sensors in their wheels. These sensors measure environmental data like 'noise pollution, congestion and road conditions'. The collected data are sent anonymously to the city in order to analyse environmental factors and measure the impact of traffic on the city infrastructure; furthermore, the data may be fed into the decision-making process when environmental or transportation issues are on the agenda" (Alaverdyan, Kucera & Horák, 2018, p. 45) (SEn2, SM1).

For smart people characteristic, LSECities (2014) reports that it can be seen that Copenhagen puts large emphasis on education and having a high-skilled workforce (SP1). The report claims that the city has one of the highest tertiary education levels in Europe, with nearly half the population having a university degree (SP1). This translates also to high levels of employment utilising the social capital (LSECities, 2014). The city is also working towards improving adult education and continuous training collaborating with employers, labour groups, and civil society partners (LSECities, 2014) (SP2).

For smart economy, Copenhagen focuses on supporting innovation and R&D through investments, ranking as one of the top OECD countries investing in R&D and the expenditure in Copenhagen is even higher than the national rate, 5,3 percent in the capital region (LSECities, 2014) (SEc2). Copenhagen municipality offers also support and assistance with new companies, helping with investment opportunities, finding business partners and offering testing grounds for new technologies (Copenhagen Capacity, n.d.) (SEc1,3,4). This has resulted the city being the headquarters for many large companies in Denmark, global corporations as well as thousands smaller companies (LSECities, 2014) (SEc3).

Table 4: Smart City Copenhagen Analysis

smart mobility	**smart governance**	**smart environment**
clean technology clusters (LSECities, 2014) SM1	app for citizens' feedback for the municipality (Bjørner, 2021) SG1	Incentives for sustainable energy production (Damsø, Kjær & Christensen, 2017) SEn1
cooperation on technologies between stakeholders (Copenhagen Capacity, n.d.) SM2	policies supporting innovation (LSECities, 2014) SG2	green transport (Damsø, Kjær & Christensen, 2017; Alaverdyan, Kucera & Horák, 2018; LSECities, 2014) SEn2
data collection for environment (Alizadeh, 2021) SM3	not citizen centric (Camponeschi, 2021) SG3	decreasing emissions through low carbon policies (Damsø, Kjær & Christensen, 2017; LSECities, 2014) SEn3
data-driven solutions (Alizadeh, 2021) SM4		efficient waste management (LSECities, 2014; Bjørner, 2021) SEn4
digitalising services (Copenhagen Capacity, n.d.) SM5		energy efficiency (LSECities, 2014) SEn5
good public transport access (Damsø, Kjær & Christensen, 2017; LSECities, 2014) SM6		fossil fuel taxes (LSECities, 2014) SEn6
		green spaces (LSECities, 2014) SEn7
smart living	**smart people**	**smart economy**
non-inclusive development (Camponeschi, 2021) SL1	highly skilled workforce (LSECities, 2014) SP1	investment in innovation (LSECities, 2014) SEc1
	lifelong learning (LSECities, 2014) SP2	investment in R&D (LSECities, 2014) SEc2
		setting up industries in the area (LSECities, 2014; Copenhagen Capacity, n.d.) SEc3
		supporting enterprise and SMEs (LSECities, 2014) SEc4

5 Discussion

It can be seen that there are various types of smart cities all over the world, who prioritise different aspects of the smart city concept. It seems that all the analysed cases emphasise the importance of digitalisation and technological advancement. All the cities have created technological hubs for cooperation between different actors for further development of technology as well as acting as testing grounds for different innovative ideas.

Mobility and transportation being one of the core aspects of SCs, it is found from the analysis that many of the cities have created well-designed public transport infrastructures, making it easier and more efficient to use, and creating a good connection between different areas. Here, the only exception is Dubai, where, at least literature, has not focused on public transport initiatives. However, in the green transportation area Copenhagen and Helsinki are thriving with the good use of public transport as well as creating infrastructure for more bike usage (Damsø, Kjær & Christensen, 2017; Alaverdyan, Kucera & Horák, 2018; Hielkema & Hongisto, 2012), whereas Singapore is more focused on public transportation in the sense of creating autonomous transportation modes (Cavada, Tight & Rogers, 2019; Shamsuzzoha, Nieminen, Piya & Rutledge, 2021).

Additionally, most of the cases emphasise the availability of open data as a driver for business creation and innovation towards urban solutions again with the exception of Dubai, where the absence of it has been criticised (Mohasses, 2019). Analysis shows that all the cities have also highlighted the digitalisation in the local administration processes, making it more accessible to the citizens, using online platforms for governmental services, for either giving feedback or using online identification systems for public services (Badran, Smart-Governments for Smart Cities: The Case of Dubai Smart-Government, 2019; Cavada, Tight & Rogers, 2019; Hielkema & Hongisto, 2012; Bjørner, 2021).

The characteristic for smart environment is quite different in the chosen cases. Copenhagen and Helsinki have strategies in place for renewable energy systems, where in the former, a lot of energy is sourced through wind power, and the latter is giving opportunities to citizens to rent

local PV panels (Damsø, Kjær & Christensen, 2017; Martikka, et al. 2018). Singapore and Copenhagen are also focused on efficient use of energy and making energy efficient solutions more accessible to citizens, the same goes for the cities' waste system (LSECities, 2014; Bhati, Hansen & Chan, 2017). However, it seems as if Dubai has not put a lot of effort into environmentally sustainable policies and changes (Hozaim & Vishwesh, 2017).

The smart living characteristic has various inputs from different cases, in Singapore, there is large emphasis on safety in the city space using a large network of cameras and surveillance systems as well as an elderly monitoring system contributing to safety (Johnston, 2019). Dubai has put similar emphasis on safety, however their main focus is on creating the "happiest city on earth" putting a lot of emphasis on the well-being of the citizens (A. Al-Azzawi, 2019). Helsinki is also implementing systems regarding the elderly population and ICT solutions targeted towards them. Copenhagen however received criticism based on development, that was non-inclusive to citizens in different areas (Camponeschi, 2021).

Smart people index is mostly focused on educational programs, where Singapore and Dubai are putting emphasis on digital and IT programs (Mahizhnan, 1999; Zakzak, 2019), And Helsinki and Copenhagen are focused on having a high-skilled workforce for SC development and the latter also puts emphasis on lifelong learning (Hielkema & Hongisto, 2012; LSECities, 2014).

The analysis shows that smart economy is in many cases highly intertwined with the digitalisation processes as well as governmental funding toward digitalisation, scientific research and R&D. Dubai and Helsinki are also organising either hackathons in the first case or just focusing on creating a competitive environment in Helsinki that is creating drive and innovative outcomes for the SC concept (Zakzak, 2019; Boes, Buhalis & Inversini, 2015). Singapore is highly focused on digitalisation and providing co-operation opportunities between stakeholders as well as investing in promising tech-solutions which is also relatable to Copenhagen (Lim et al. 2020). The last country offers also a lot of help and support to different new enterprises and small companies (LSECities, 2014).

Based on the analysis it can be seen that all chosen cities have put tremendous efforts into developing their smart cities, however the focus for them varies in some respects. It can be seen, why Singapore has been rated the number one smart city in the world (IMD-SUTD, 2020). They have a well-rounded approach incorporating in all aspects of the smart city framework,

providing efficient urban solutions to the citizens as well as focusing on developing digitalisation of the urban area. Copenhagen seems to thrive in the field of environmental sustainability, offering green transportation networks as well as sustainable energy production. Helsinki is prioritising its technological development through Living Labs and the availability of open data. They are also accentuating on creating a strong bottom-up approach incorporating citizen feedback. Dubai has only been working on smart city solutions for four years, therefore, there are still many areas, that could be improved upon, for example the environmental sustainability aspect. However, the city is emphasising on e-government solutions, taking user feedback into account, and creating efficient public services for their citizens.

The analysis shows that cities today find digitalisation of inclusive public services and user feedback to be one of the main solutions to urbanisation, complemented by a well-designed network of public transportation and offering solutions alternatives to car use. They also emphasise on creating technology hubs and competition as well as giving incentives for business creation and investing in innovative companies.

There are also areas, where some of the cities are lacking, for example, Dubai could improve upon their environmental strategies which is a criticism that can also be applied to Singapore and Helsinki. For Copenhagen, it can be said they could be more citizen-centric and practice a more bottom-up approach.

6 Conclusion

In conclusion, it can be said that smart cities today share many qualities, like digitalisation, emphasis on quality of life and investing in innovative solutions. However, some, like Copenhagen, have focused more on the environmental side of smart cities than others, whereas Singapore is leading when it comes to safety and surveillance systems. Dubai's focus is on increasing the quality of life for its citizens by using technology and digitalising services and Helsinki has aimed their attention at creating a diverse local technology hub for generating innovative ideas and acting as a testing ground. Therefore, it seems as if there is no clear difference between Nordic smart cities compared to the ones outside the region. However, some differences of priorities can be noticed, like for Singapore and Dubai, there have been more emphasis on surveillance and safety measures, whilst in the Nordic region, the cities have focused more on offering renewable energy solutions.

The main question the thesis aimed to answer was "how are smart cities today tackling the main challenges driven by increasing urbanisation and climate change?" To find an answer, it was decided to collect secondary data and use a Giffinger et al. (2007) smart city framework to shape the analysis and give a more structured overview of four different smart city cases, which were Singapore, Dubai, Helsinki and Copenhagen.

It was found that the cities are focusing on offering digitalised public services whilst making them more efficient and accessible for the citizens. There is also an emphasis on government support on Living Labs, Technology hubs, business creation and collaboration between stakeholders for innovative ideas. Climate change however seems to be an issue, that many smart city concepts are yet to tackle. There is movement toward more efficient energy use, incentivising using the public transportation as well as setting up sensors and application for gathering data about the surrounding environment.

6.1 Future Research

As smart city literature is still quite a new area, there are many ways to contribute into future research. Researchers could focus on evaluating different case studies, as improvements are made at a fast pace. This would give insight into measures that have either successfully implemented in some areas, or failed, giving other smart city initiatives inspiration on future endeavours and ideas.

Even though the smart city concept is more prominent in developed countries, there are some initiatives happening in developing areas as well. It would be interesting for further research to focus on the smart city implementations in developing areas, either through case studies or also comparing how are the priorities differing in these areas as the income level is diverse.

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