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Market Opportunities in Smart Cities

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In this thesis, market opportunities in "Smart" cities were studied. "Smart" cities refer to cities that have adopted the latest technologies and sensors to support their day-to-day operations. With these technologies, cities can achieve significant savings in their operations in terms of time and money. Furthermore, these technologies can help the cities to reduce their emissions and environmental impact.

The thesis was carried out with practical research approach. First, the best techniques for identifying market opportunities from the literature and various sources were studied. Following the literature review, an analysis of Smart city verticals and cities was performed based on the conceptual framework created in the literature review. Based on the information obtained from the analysis, conclusions were drawn for the case company.

Market opportunities in "Smart" cities were studied from the results of the Esithoughtlab research company global initiative as well as from other sources provided by the case company. Based on the results of the work, the case company should have a better understanding of where to invest in "Smart" cities. These markets are expected to grow in the future with continuing urbanization. Since the market for "Smart" cities is still new, it is reasonable to do comprehensive research so that the company can save time and gain efficiency before entering the market.

Keywords	Smart City, 5G, SWOT, ROI

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Insinöörityössä tutkittiin markkinamahdollisuuksia "Smart" kaupungeissa. "Smart" kaupungeilla tarkoitetaan kaupunkeja, jotka ovat ottaneet käyttöön viimeisintä teknologiaa ja sensoreita päivittäisten toimintojensa tueksi. Näiden teknologioiden avulla kaupungit voivat saavuttaa merkittäviä säästöjä toiminnoissaan ajan ja rahan suhteen. Lisäksi nämä voivat auttaa kaupunkeja vähentämään päästöjään ja ympäristövaikutustaan.

Opinnäytetyö toteutettiin käytännön tutkimuksella. Ensimmäiseksi tutkittiin parhaita tekniikoita markkinamahdollisuuksien tunnistamiseen kirjallisuudesta ja erinäisistä lähteistä. Kirjallisuustutkimuksen jälkeen suoritettiin analyysi, joka pohjautui kirjallisuustutkimuksessa luotuun käsitteelliseen viitekehykseen. Analyysista saatujen tietojen perusteella kohdeyritykselle tehtiin johtopäätökset ja ehdotukset tulevaisuutta varten.

Markkinamahdollisuuksia "Smart" kaupungeissa tutkittiin Esithoughtlab tutkimusyhtiön laajan tutkimuksen tuloksista kuin myös muista kohdeyrityksen antamista lähteistä. Työn tulosten perusteella kohdeyrityksellä tulisi olla parempi ymmärrys mihin investoida "Smart" kaupungeissa. Näiden markkinoiden on odotettu kasvavan tulevaisuudessa jatkuvan kaupungistumisen myötä, joten aika tutkimukselle oli erittäin hyvä. Koska "Smart" kaupunkien markkinat ovat vielä uudet niin ennen markkinoille siirtymistä on hyvä tehdä kattavia tutkimuksia ajan säästämiseksi ja tehokkuuden saavuttamiseksi.

Avainsanat	Smart City, 5G, SWOT, ROI

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1   Introduction

Investments towards "Smart cities" are growing all the time. The ways to make city services and infrastructure connected and collecting data is becoming more and more interesting for major cities because new technologies such as 5G is making it easier and more approachable.

For people who live in a "Smart City" changes in life may not be very noticeable, but the indirect effect is significant. Surveys have shown that the ease of life and services are substantially better. Furthermore, the use of the new technologies and implementing these into everyday life makes the cities more attractive for new inhabitants when they are comparing which city to move into. [451 Research Custom Survey. 2018.]

Research made by "451 Research forecasts" estimates that the investments towards Smart cities digital infrastructure are going to grow from 36.6 billion $ in 2019 to 47.4 billion $ in 2025. The growing urge to invest in digital infrastructure enables companies to develop even better solutions for the market. This thesis focuses on near-future market opportunities in Smart cities situated in Europe.

1.1   Business context

Nokia is a Finnish network communication company that was founded in 1865 and its vision is to make people's life easier by using the newest technology. Their main business areas are network infrastructure, developing, and licensing technologies such as 5G and they deliver the industry's only end to end portfolio in software services and licensing globally. Their customers include companies that support the network to 6.1 billion subscriptions. Through their research team which includes Nokia Bell Labs, they aim to make the 5G network widely available for everybody.

The 5G network is at its early stage now but the market is evolving quickly. The first of the 5G networks went live in early 2019. Nokia's 5G services help service providers and enterprises deploy and operate 5G networks more efficiently and faster by providing end to end services. [Nokia 2020.]

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5G makes the implementation of Smart technologies even easier for the cities. Now the current 4G LTE technology cannot handle the vast amount of data that comes from the various IoT sensors in "Smart" cities. That is why widespread deployment of 5G is one of the conditions that must be filled before Smart cities can get to their full potential. Also, services around the Smart technologies are at an early stage. Monetization models and new approaches must be considered so that investors and cities get more interested in these new technologies.

1.2   Business challenge and objective

5G technology paves the way for new Smart city solutions and service opportunities but those are yet to be discovered. Emerging new technologies are opening interesting new ways for cities to offer services for their inhabitants. The challenge at this moment is to find the most lucrative near-future market potential. The problem with smart city projects is the low Return on Investment and that there is no proof that all the Smart city initiatives are successful. There is no clear investment area that brings direct income for the cities or investors but most of the income is indirect and is obtained sometime after the project has been finished and deployed into use.

Until now some cities have deployed Smart technologies and sensors in various areas without a specific plan. To get most out of the Smart technologies cities should make one big system rather than many small systems. The cities can accelerate revenue streams through efficiency gains if they deploy Smart technologies in the right way with a clear plan.

The Objective of this thesis is "to identify the most lucrative near future (2020-2023) market opportunities in the verticals found in the Smart Cities database" for the case company. With the proposal from this thesis, the case company should know what to look for when considering new areas in the Smart City market.

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1.3 Project plan

Objective: To identify the most lucrative near future (2020-2023) market opportunities in the verticals found in the Smart Cities database

Literature
- Literature study to find the best methods/tools to use in this study
- What is "5G" and "Smart city"
- Hyperconnected Cities Program
- What to consider when Identifying market potential

Outcome
"Conceptual Framework"

Analysis Data 1 & 2
- Vertical analysis
- Identifying the current challenges and possibilities in the Smart city verticals
- City analysis with the help of Conceptual Framework
- Database content
- Relevant data in the data-base for this study
- Analysis of 9 European cities on different levels
- Analyzing different areas
- Summary of the most potential investment areas in different cities

Outcome
List of all the potential market opportunities

Proposal Data 3
- Based on the findings in the data-base analysis
- Summary of proposal of the most potential market opportunities
- Ranking the market opportunities from most potential to unlikely
- Future research

Outcome
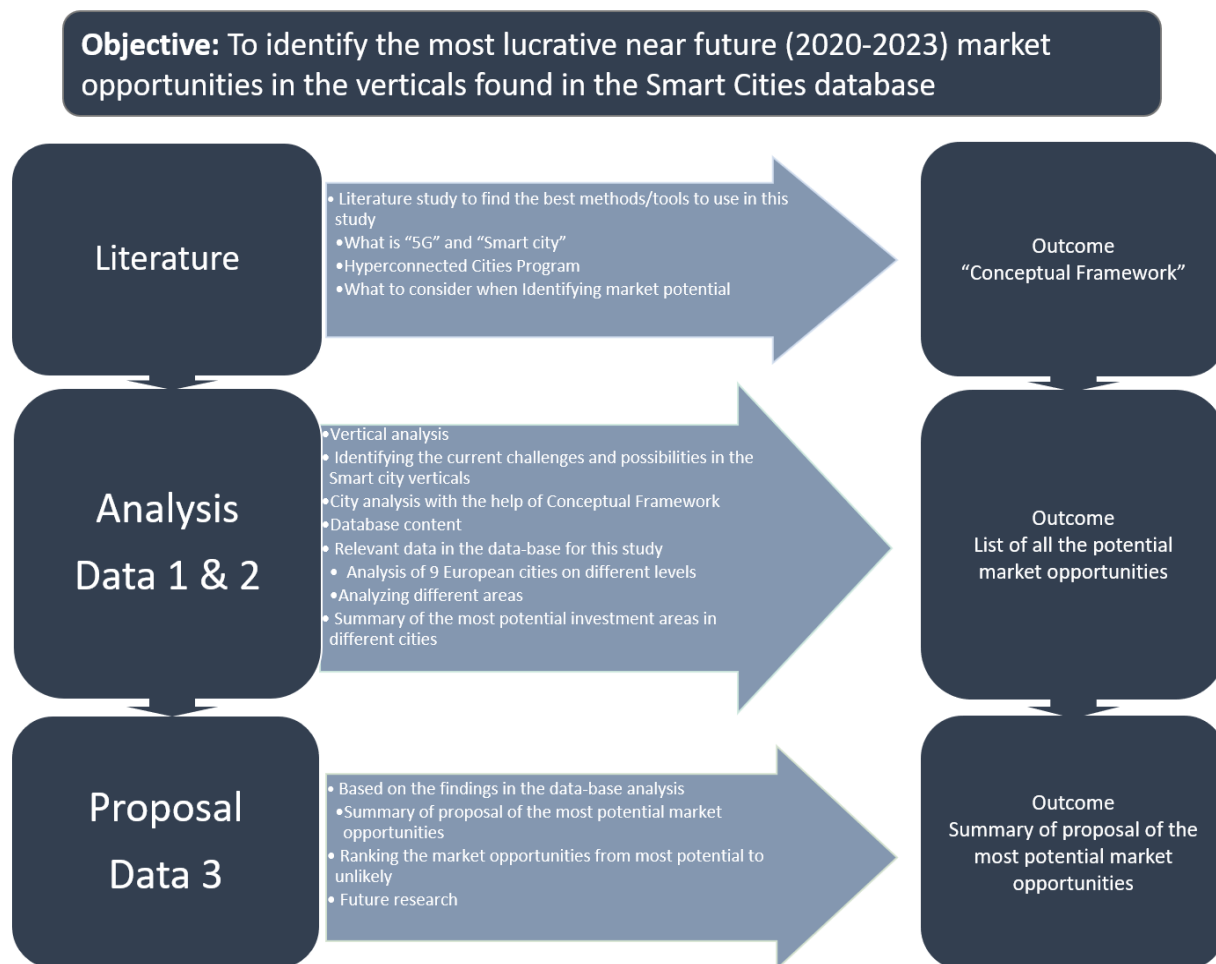Summary of proposal of the most potential market opportunities

Figure 1.   Flowchart

As shown in figure 1 Flowchart the project plan consists of three steps. Literature study, analysis of data 1 & 2, and Data 3 proposal. The literature part studies the technologies and best practices when identifying market potential. The outcome of this part is the conceptual framework.

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Data plan				
	Content	**Input**	**Tools**	**Output**
Data 1 Vertical analysis with SWOT	• Vertical analysis using SWOT	• "Building a Hyperconnected City" Report	• SWOT	• Summary of the Vertical Analysis
Data 2 City analysis according to CFW to identify the most potential market opportunities in different cities	• City-analysis using the conceptual framework • Description of the data-base • Analysis of the data-base	• Hyperconnected Cities Data-base	• "Conceptual framework" made in the literature study	• Summary of the most potential market opportunities
Data 3 Ranking and describing most potential market opportunities	• Description of the most potential market opportunities	• "Building a Hyperconnected City" Report	• Findings in Data 1 & 2	• Summary of proposal of the most potential market opportunities • Business areas ranked from most potential to unlikely

Table 1.   Data plan

As shown in the Table 1 Data plan the Data 1 is analyzed using SWOT. Data 1 consists of data found in the building a hyperconnected city report and the output is the summary of the verticals. Data 2 was analyzed with the identified tools in the literature study and the outcome is the summary of the most potential market opportunities. Data 3 is based on the findings in the analysis of the Data 1 & 2.

2   Good Practice of Identifying Market Opportunities in Relevant Literature

This chapter introduces some of the technologies which are needed to make a city "Smart" and the tools found in the literature used for making the city and vertical analysis. The tools are then used to create the "conceptual framework" which is applied in the analysis part of the study.

2.1   5G technology

5G is the next generation in wireless communication networks. With 5G mobile devices can have at least ten times faster download times compared to current technology. For example, with 4G LTE downloading high-definition film takes ten minutes or longer but with 5G it could take only one second. The capacity of the 5G network is also ten times

bigger than in the 4G LTE network, therefore more users can use the same base station at the same time. Additionally, 5G enables IoT and smart devices connected to the internet more efficiently. It is as well more reliable than the current technologies used, thus it can be used to control equipment that requires liability and accuracy, for example, remote surgical machines. [Nordrum, 2017.]

Latency, which is the required time for data to travel between two points is going to be even as short as one millisecond when using 5G which is many times shorter than the average latency of 50 milliseconds in 4G LTE networks. The shortened latency brings many possibilities to the field of wireless communication. For example, gamers can play games straight from the cloud by using 5G. That removes or makes smaller the need for local storage. With smaller SSD or Hard drives, gaming equipment can be smaller but at the same time much more efficient which opens the possibility for Virtual Reality games and other applications. In theory, only the smaller latency brings endless possibilities to the wireless communication field. It is just dependent on what companies and engineers can develop. [Nordrum, 2017.]

5G uses millimeter waves instead of radio waves used in current wireless communication technology. With current technology, the problem is that users do not have enough bandwidth in use. Less bandwidth causes users to have slower connections and disconnection problems. However, the use of millimeter comes with a major problem, millimeter waves cannot easily travel through obstacles or buildings. Because of this problem the 5G network is going to consist of many small cellular base stations rather than from a couple of huge towers like 4G LTE. Small cells can also handle the increased capacity in demand. [Nordrum, 2017.]

5G uses a new technology called massive MIMO which means "Multiple Input Multiple Output". Current 4G LTE networks use eight transmitters and four receivers to handle the data. 5G is going to use even 22 times more ports to handle the huge amount of data and connected devices. There are also environmental issues in 5G technology. Because of the vast amount of 5G antennas and base stations needed to connect users to the network the energy usage in the 5G network is going to be a lot higher than in current technology. However, as the technology continues to develop the base stations are going to be more energy-efficient and the cell towers can also use small solar or wind generators. Millimeter waves can also disrupt satellites that are used to monitor the weather,

but the companies have a certain wavelength that they must utilize so that 5G antennas would not disrupt satellites and other equipment. [Curran, 2020.]

2.2   IoT

Internet of Things is a collection of sensors, devices, machines, or even whole cities that are connected to the internet and can be remotely controlled. These devices etc. collect information about their surroundings all the time. The data collected can be used in various ways, for example, to optimize processes and make businesses more profitable. The use of the internet of things opens whole new business models for companies. Some examples of this are remotely controlled machines and predictive maintenance. [Telia, 2017.]

The utilization of IoT is expected to grow exponentially in the future, especially in the smart cities. Now there is little practical examples of IoT full potential, but many pilot projects are made in rising numbers. Companies are not sure if the new technology can do what it promises. This is usually the case when new technology is introduced into the field of business. The next big leap in IoT is the use of 5G because it helps to reduce the latency to one millisecond and makes the data transfer faster. [Telia, 2017.]

2.3   Smart City

According to the European Commission: "A Smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and businesses. [European Commission: Smart City, 2016.]" The phrase "Smart City" does not mean anything certain but usually it is connected to technology in some way. A smart city is an entirety of connected services and people. Future cities have to offer ease of life and wellbeing for its citizens. It must also create a beneficial environment for the companies and at the same time develop its sustainability because urban areas are responsible for 70% of global energy consumption and greenhouse gas emissions. Implementing Smart city technologies can help reduce consumption and greenhouse gas emissions. [ISO, 2020.]

In a Smart city, modern technologies are used in all its different operations such as energy production, waste management, logistics, etc. In the heart of the smart city, there is the idea of sustainable and continuous development. Achieving this development requires implementing Smart technologies in different areas and making everything work as one. Some cities have just started implementing Smart technologies and IoT sensors into their operations but most of the projects are in the early stage therefore there are only short-term results available. In the future when the cities have gathered more data the true impact of these projects can be seen. [Karpinski, 2019.]

Smart technologies can also be used to help cities and health officials fight diseases. Smart sensors and surveillance equipment give the officials the possibility to track people. For example, in 2020 the South Korean government and some cities in the United Kingdom used data collected from Smart sensors to see if people were following social distancing rules during the Coronavirus pandemic. Various Indian cities were also using Smart technology to trace and monitor people in quarantine. These experiments had a positive impact on the pace that the Covid-19 spread. However, the possibility that city officials and government can trace individuals worries some people because this kind of technology can be dangerous if used in the wrong way. However, in the European Union its legislation prevents governments and cities to use the data in the wrong way. [Chandler, 2020.] [GDPR legislation.]

2.4 Hyperconnected cities program

Hyperconnected cities is ESIthoughtlab driven program. Sponsors and research partners include large multinational companies that specialize in urban innovation and development. The program aimed to gather benchmarking data from 100 cities so that the cities would have an evidence-based roadmap for the planning of the future. Digital change is happening so fast that the urban leaders cannot keep their city on the same page with the stakeholders. Some results that have come from the first Smart city initiatives are lower crime rate, cleaner air, and fewer traffic jams as well as higher productivity, improved public health, and better living conditions [ESI, 2019].

In this program practices, plans, and performance results of the cities were gathered. The data was gathered from different cities in which some were already adopting a wide range of smart city technologies in everyday use and some did not use these technologies or were just starting to implement these. Cities were categorized into three levels according to their level of maturity. The levels are "Leader: Ahead of most peers in interconnecting urban ecosystem and seeing significant economic, business, and social benefits, Advancer: Making progress on the interconnecting urban ecosystem and realizing benefits, and Implementer: Making strides and investments to interconnect urban ecosystem". By categorizing the cities, they were able to analyze the investments, strategies, and technologies that bring the highest Return on Investment for the cities. They also recognized some of the problems that might come on the way. [ESI, 2019] More information about the problems can be found in Chapter 3. Smart city analysis.

So that it can be better understood how cities use technology and data to interconnect and transform urban ecosystems the research program was conducted as a four-pronged study. These steps are described below.

1. **Benchmarking Survey of 100 cities worldwide**

   Cities were surveyed about their use of technologies, data, and analytics. The benchmarking data was collected from the whole urban ecosystem. Data from investments, outcomes, and returns were also collected. Return on Investment data was self-reported by the cities.

2. **Hyperconnected cities index**

   A team of economists developed a maturity index based on the survey data. The cities are ranked by their progress in four key areas which are Data and Analytics, Technology, Citizen Engagement, and Cybersecurity. Rankings differ from other outputs because different dimensions of connectivity were measured.

3. **Secondary city data from trusted sources**

   The economist also collected data from trusted secondary sources to augment the survey data. The data measures performance of city services and quality of life. Findings were integrated into the data tool called hyperconnected city navigator.

4. **Insights from urban leaders and smart city experts**

   In-depth interviews with city officials were conducted to identify best practices in smart cities all around the world. The basis for the case studies was constructed from these interviews.

Since most of the data was self-reported the research team conducted quality control to ensure accuracy. The quality control included third-party analysis and rechecking the survey inputs. This ensured that the data was valid and useful. Even though the cities provided the program with their best estimates, the analysis must be viewed as directional and work in progress. [ESI, 2019.]

According to Stevens (2012) analysis of market involves: identifying market, identifying market factors, estimating market potential, and estimating the revenues from a given venture. The best way to identify market potential is to use already existing market factors. The study made by ESIthoughtlab (2019) defines the market factors in the cities. First the cities technological Infrastructure maturity was analyzed. If the city's IT-infrastructure was not developed enough it induced problems when implementing Smart technologies. Smart technologies need advanced IT-infrastructure for effective use because the systems and sensors run on data and the infrastructure must be ready to handle the large amount of data that the systems produce.

The first two factors were the areas of Current Priority and anticipated investment change rate for the city. If the city did not have an interest in the area and if the investment change rate is negative, then it decreased the area's ranking. The third factor is the project start time. If the project started a long time ago and most of the initiatives are already deployed into widescale use most likely the area is not interesting anymore and the city officials' interest is already in the next area. [ESI, 2019.]

The total return on investment is just an estimate and it does not apply to all projects because the cities are so different from each other, but it gives a good understanding of what the possible ROI can be. External analysis supports the deductions made in the internal analysis. [ESI, 2019.]

2.5   Market Segmentation and SWOT

According to Stevens (2012), what is sometimes referred to as a market for a product or service is a composite of smaller markets each with identifiable characteristics. Market segmentation makes market analysis easier as the market is in smaller pieces and it is the basis for market analysis. The segmentation can be done by recognizing the characteristics of the market and distributing those into own segments. The identified market segments can be analyzed using SWOT so that a deeper understanding of the segments can be obtained.

SWOT-analysis is a tool that is used by businesses to create an overall picture of a strategic situation to help in decision making. The acronym SWOT comes from the words Strengths, Weaknesses, Opportunities, and Threats. With SWOT analysis it is possible to view strategic situations by comparing strengths and weaknesses to opportunities and threats created by the competitive environment. The idea is to create an analysis which is then used to make decisions and strategies. [Vuorinen, 2013.]

	Positive	Negative
Internal	Strengths	Weaknesses
External	Opportunities	Threats

Table 2.   Swot 4x4 matrix

SWOT analysis can be made into a 4x4 matrix which helps in the visualization of the analyzed area. An example of this matrix is shown in Table 2. One of the limitations of SWOT is that by itself it cannot show what the right decisions to make is. Usually, internal, and external factors change rapidly so the results may change too. However, SWOT can be used as a foundation for evaluating limitations and potential in the market. [Vuorinen, 2013.]

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2.6 Conceptual Framework

The conceptual framework (Figure 2) was built from the identified market potential analysis tools in the literature study. It consists of three steps which are Market segmentation, SWOT, and City analysis.

Conceptual Framework

Identifying market potential

Market Segments (Stevens, R. 2012)

SWOT (Vuorinen, T. 2013)

City analysis (ESI. 2019)

1. Interest level
2. Anticipated Investment change rate (Trend)
3. Current projects status and starting time
4. Current initiatives ROI
5. ROI

Figure 2.   Conceptual Framework

Market segmentation is used to cut the market into smaller parts which all have their distinct characteristics. The market segments are analyzed using SWOT. As the SWOT analysis gives a deeper understanding of the verticals these can be used to support the analysis of the cities and future decisions when cities consider new areas where to start the use of Smart technologies.

The second part of the analysis is the city analysis. The result from the city analysis is the city segments ranked from best to worst in the chosen cities. The factors to the city analysis are based on the hyperconnected cities program part in the literature study.

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3   Smart City Analysis

This section covers some of the benefits and data in the Smart Cities. Moreover, the five main market areas of the smart cities are analyzed. The market areas are Mobility and Transportation, Energy and Water, Environment and Sustainability, Public Safety and Health, and Governance and Funding. The market areas are analyzed by using SWOT which is introduced in the literature section of this study.
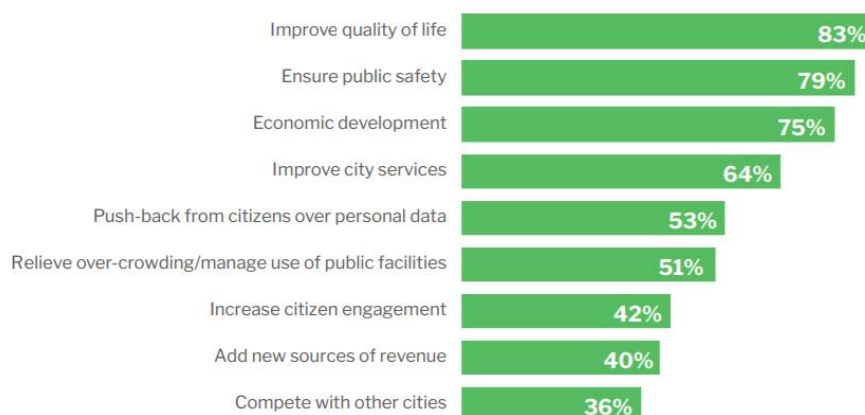
3.1   Data and Benefits of Smart City

Smart city creates new service models that use possibilities brought by data and technology. New technology cannot be counted as "Smart technology" automatically but it also needs the "Smart" ecosystem around it so that the user experience and quality of life are improved. Now the market is full of modern sensors that can be bought by everybody but there are no services included in these sensors. The main problem is to determine how to make these new services profitable enough so that positive income is achieved.

Retrofitting is one possible way to make the city "Smarter". The problem with retrofitting is that it is many times more expensive and harder than just building a Smart city from scratch. However, retrofitting old houses and parts of the city with modern technology can pay itself back many times over. [Mustonen, V. etc. 2014.]

One possibility that comes with a Smart city is the improvement of energy efficiency and recycling rate which saves vast amounts of money for the city and that saved money can be redirected to better use. That is why recognizing wasted resources is such a huge business opportunity. These can be for example carsharing or forwarding empty business premises to more users.

In the overall infrastructure of the city, the largest possibility in Smart City applications comes from the passive effects which are for example improved quality of life and better resource management. The effects can be seen rather slowly but after some time the effect can be even calculated as positive ROI. However, as the effects are coming slowly and are more socio-economic than active income, it makes the reasoning for new Smart

city initiatives even harder. The cities must change their thinking more towards the inhabitants rather than the investors and money. In the figure 3 Benefits of the Smart Cities there are some of the benefits found in the survey made by "451Research" in 2018.

Figure 3 Benefits of the Smart Cities

Big data has an important role in smart cities. Internet of Things and sensors collect enormous amounts of data all the time. Also, all the inhabitants in the city create data all the time by using phones and apps in the public networks. Over four billion people own smartphones thus almost every corner of society can be analyzed. Efficient data analytics tools and methods must first clarify this data so that it can be used in making the data more useful. Large multinational companies have a wide role in making smart cities possible. These companies can spread successful projects to other countries and by collaborating with other companies create standards for the technology. [Mustonen et al. 2014.]
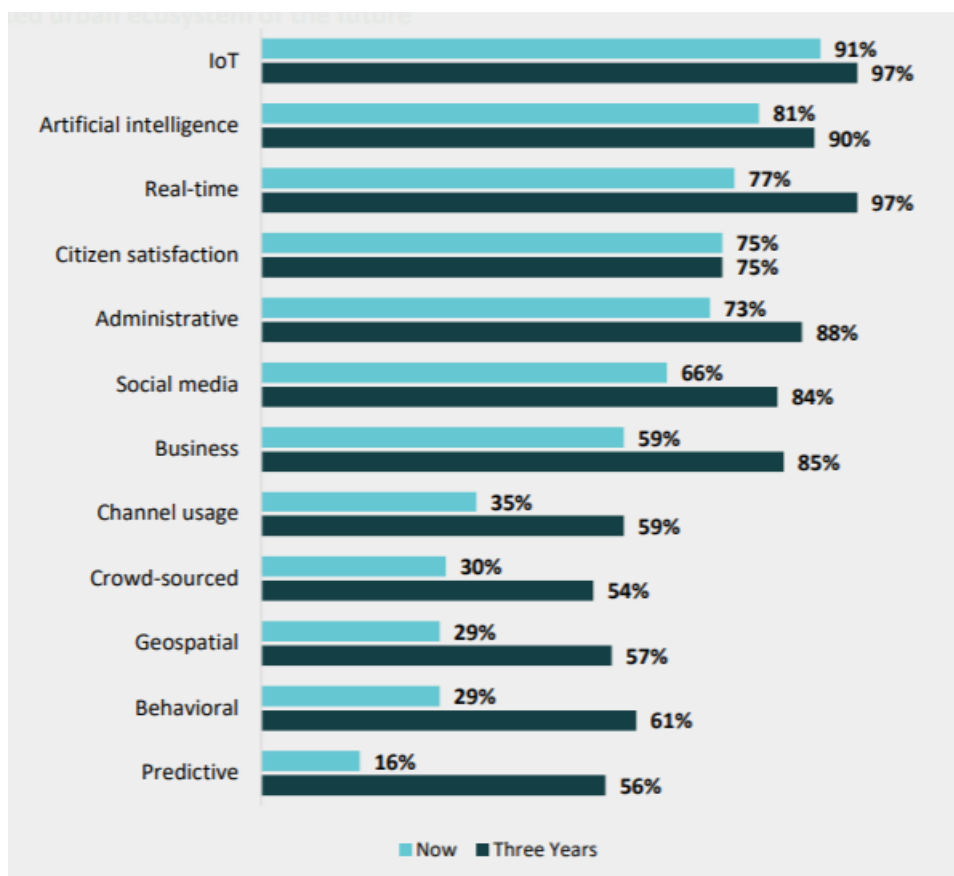
Figure 4 Percentage of cities using different types of data today and in three years

Smart cities run on data. Cities can collect traditional data from city departments, local businesses and citizen surveys, or new types of data from Artificial intelligence, IoT, and social media. This data can be used to predict the behavior and development of the city. Thus, cities can boost their performance and services exponentially. Figure 4 shows the percentages of cities using different types of data today and in three years. Most of the data in modern cities comes from IoT devices. 91% of the cities already use this for their advantage and that figure is going to grow to 97% in the coming years. Today crowd-sourced, geospatial, behavioral and, predictive data are not so widely used but the growth is predicted to be enormous in the next three years. [Celi, 2019.]

3.1.1 Open Data

Open data is data that is collected by governments, cities, or companies and it is free for everybody to be downloaded and used. To classify Data as open it must fulfill four criteria which are:

1. **Publicity:** Data must be public so it can be opened. The data cannot contain any personal details or business secrets.

2. **Machine readability:** The data is opened in a form that is easy to process with computer software. For people, PDF or HTML are better formats to read but for computers, it is easier to process CSV-, XLS- or XLM-formats. Machines can also use a straight link to the data source.

3. **License terms allow reuse:** The data provider allows the data to be reused and clearly states this in the terms and conditions found together with the data. If the terms are unclear this might make the data unusable.

4. **Free to use:** The data is free and can be downloaded from public sites.

Companies that utilize open data and big data make more new innovative products and services for the market compared to the companies that do not use these. Companies in the information and communication sector that used data in innovations grew their sales, on average, 17% more than other companies. [Koski et al. 2017.] Clearly by using data companies can make more profit.

However, using the data efficiently can be a problem. Searching and identifying the right data from the database can be enormous work for humans but modern data analytics systems can do it much faster. Sometimes only 1% of the information in a huge pile of data is used and utilized for further purposes. Using data more efficiently would make the decision that is based on the data even better. However, it is almost impossible to utilize all 100% of the data found in a database because some of the data might be corrupted or irrelevant. However, even a 5-10% rise in used data would benefit the decision making even more.

Expected results from the use of open data are for example new products from companies, making operations more efficient using data-based decision making and the emergence of new businesses. At its best using data creates growth and improved productivity for companies. Citizens see most of the benefits as a more efficient use of time. Organizations that operate in the public sector can also use open data for their advantage when making services more efficient for the citizens.

The problem when trying to evaluate the impact of open data is that it is impossible to know how people are using it. The information that somebody downloaded the data is not enough. This can only be solved by making regular surveys for customers. Also, the companies can use open data and purchased data at the same time which makes it impossible to know what the impact of open data is. Websites that offer open data should ask customers more frequently how they use and benefit from the data. [Koski et al. 2017.]

3.2   Vertical analysis

This chapter analyzes the different areas (Figure 5) of Smart City. This analysis of the Smart City areas will also be used to support the identification of market opportunities in different cities. All the total ROI figures can be found in Appendix 1.

Figure 5 Smart city infrastructure [ESI, 2019]

For this study, the most relevant verticals in the Hyperconnected cities database are the ones with more data, and which have some figures from current or past initiatives and the ROI figures have been calculated. These verticals are Mobility and transportation, Energy and Water, Environment and Sustainability, Public Safety and Health, Governance, and Finance. [ESI, 2019.]

3.2.1 Mobility and Transportation

Strengths	Weaknesses
• Traffic management applications have a high ROI • The easiest place for implementer cities to start from • High growth in anticipated investments • 96% of leader cities already use real-time traffic management systems • Funding comes straight from the city budget • Offer both financial and quality of life benefits	• High cost of the public transit projects • Large scale of the projects in public transit • Projects can fail due to changing social environment or lack of interest • Hard to predict the future usage
Opportunities	Threats
• Public transit has a positive impact on the environment • Traffic management helps to reduce harmful emissions in the city centers • Lot of competitors	• High cybersecurity vulnerability • A lot of competition in the transportation business

Table 3 SWOT matrix of Mobility and Transportation

Table 3 shows the SWOT matrix made from Mobility and Transportation market area. Mobility and transportation are usually the places where the cities start to utilize smart technologies. The main reason is that usually public transit and traffic management offer large benefits and high ROI figures. Leader cities benefit most in this area, the leader city ROI can be even four times higher than in the Implementer cities.

The main benefits in public transit are higher passenger satisfaction, an increase in on-time arrivals, greater passenger satisfaction, higher transit ridership, and increase access to employment opportunities. The biggest weaknesses in public transit projects come from the high cost of the project and the difficulty in making a forecast of the project's success. Public transit is usually managed by the city itself so there is a lot of bureaucracy in these projects and it might take a lot of time to start a new project.

The main benefits of traffic management projects are Improved productivity and delivery times in e-commerce, reduction in emergency response times, travel costs, congestion, and vehicle accidents. There is a lot of data available on transportation management projects because, for example, 96% of the leader cities have already adopted real-time traffic management systems so these projects have existed for a long time already. It is very useful that traffic management projects have been around for a long time, as more data is available. The small amount of data makes the conclusions uncertain and it is almost impossible to say with certainty whether a project is useful for the city or not.

In cities that do not yet have many smart city systems in place, it would be a good idea to start the utilization of Smart systems around mobility and transportation. This can be justified by the fact that this area has the most data available and almost all the leading cities use mobility and transportation smart applications, so the benefits are visible.

Public transportation is such a large part of the cities infrastructure and it attracts large numbers of competitors to the area. Recent years have seen the introduction of international applications such as electric kickboards and uber. These applications are the prime example of what can be achieved with modern connections and devices. Competitors bring more projects, partners, and investors to the market with whom cities can develop new ways to manage the ways of transportation in the city. [Celi et al. 2019]

3.2.2 Energy and Water

Strengths	Weaknesses
- Water-related initiatives improve public health - Decreased water usage - Lowest cybersecurity vulnerability - Smart electricity grids offer a large return on investment - More stable energy prices - Smart streetlights provide cities with platforms to adopt various sensor technologies	- Cities adopt energy technologies slowly - Unclear investment structure - Low ROI for implementers
Opportunities	**Threats**
- Reduced pollution - Cities can save money by lowering energy usage	- Renewable electricity sources are unreliable - Water and electricity grids are vulnerable to natural disasters

Table 4 SWOT matrix of Energy and Water

Table 4 shows the SWOT matrix made from Energy and water market area. Energy and water are very important areas for cities, and often energy networks and water utilities are entirely owned by the city. Investing in energy and water smart applications will bring many positive results for cities. In addition to a good return on investment, investing in these will improve the quality of life and health of the citizens. Same as in other smart city applications, the ROI figures for leader cities are many times higher than for implementer cities.

The main benefits in energy and electricity initiatives are stable energy prices, a decrease in energy consumption, better reliability and resilience, reduction in electricity prices, and increased use of renewable energy sources. The most usual smart energy applications in the cities are Smart streetlights, electricity meters and, dynamic electricity pricing. Leader cities have been more eager to adopt smart technologies in energy and electricity area. For example, 80% of leader cities use dynamic electricity pricing but only 47% of the total cities in the benchmarking study use the same technology.

The best area to invest in energy and electricity are the smart streetlights. The smart streetlights have one benefit over other applications which is providing a platform for various sensors. 70% of the cities that have smart streetlights use those as a platform for video surveillance and 58% as a platform for traffic monitoring technologies. The problem with the energy smart applications is the unclear investment structure. Other than these mentioned applications have not had popularity amongst the cities. The potential to generate large returns just has not got the attention of the private or public investors. Also, the energy grid and renewable energy projects are unreliable and vulnerable to natural disasters.

The main benefits of water-related projects are improved citizen health and well-being, a more reliable and resilient system, a reduction in pollution and, a decrease in water usage. The one smart application which has shown that it is working well and bring good positive ROI is the real-time water quality monitoring system. 96% of the leader cities use it and the average ROI for leader cities is 5,1%. All the cities inhabitants regardless of their social status benefit from the better monitoring and controlling of the city's water systems which reduces the welfare gap between different social-economic groups. [Celi et al. 2019]

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3.2.3 Environment and Sustainability

Strengths	Weaknesses
• High ROI for leader cities • Higher recycling rate • Better citizen health and well-being • More efficient waste management leads to emptier dumps • Easy to innovate new projects • Low cost of the projects • Funding comes from the city budget	• Lower interest and adopting rate compared to other urban ecosystems • The high ROI applies only to the leader cities • Low interest of private investors • Long wait before positive income is achieved
Opportunities	Threats
• A lot of benefits which include improved health and cleaner city • Raises cities reputation and quality of life • Recycling is beneficial for the nature	• Low social interest • "Money before environment"

Table 5 SWOT matrix of Environment and Sustainability

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Table 5 shows the SWOT matrix made from Environment and sustainability market area. Waste collection and Environmental technologies are not so popular amongst the cities. Despite the possible large ROI numbers the adoption rate is much lower compared to the other areas of the urban ecosystem. Same as in the other areas the ROI figures are largest for the leader cities. A possible reason that such a small amount of the cities uses these technologies might be because of the low interest of private investors. The private sector investors' interest is hard to get because some of the environmental projects do not bring any positive income. On the other hand, waste collection technologies can create a large income from the projects. For example, leader cities get a 6,8% ROI from using digital waste tracking.

One threat is low social interest in the environment. The discussion around environment and sustainability has grown in recent years because of climate change and severe natural phenomena. However, environmental issues have low interest amongst people compared to other problems. Some people even deny that climate change and environmental problems are real. Although using these technologies can raise the city's reputation as people think that the city is responsible and sustainable.

The main advantages of the waste and environmental initiatives are an increase in citizen health and well-being, less unrecycled waste, better efficiency in waste management and, reduced litter. By reducing litter and increasing the recycling rate it is possible for cities to have smaller dumps and that area can be utilized in some other way. City inhabitants are also a lot happier when the city is cleaner. [Celi et al. 2019]

3.2.4   Public Safety and Health

Strengths	Weaknesses
• Public safety technologies have substantial impact on quality of life in the cities • Improves city reputation • Security systems decrease anxiety amongst citizens • Public safety is funded by federal support • Public health systems decrease mortality	• Low adoption rate amongst cities • Crime is not a major problem in most of the cities • Some of the cities do not provide public health services
Opportunities	Threats
• Attracts new businesses • Helps to fight the crime in the city	• Moderate cybersecurity vulnerability • Public safety surveillance and tracking systems can be misused

Table 6 SWOT matrix of Public Safety and Health

Table 6 shows the SWOT matrix made from Public Safety and Health market area. Public safety Smart technologies remain rather unpopular amongst the cities. The main reason for this is that crime is not a problem in most of the cities. However, cities that have problems with crime and adopt public safety Smart technologies see the substantial quality of life benefits. That raises the city's reputation and new inhabitants move there more eagerly. Also, funding for public safety initiatives can be acquired straight from the federal budget. The main benefits of public safety initiatives include a better reputation of the city, an increase in citizen well-being, higher citizen engagement, decreased anxiety amongst citizens and, the attraction of new businesses.

People like to establish a new business in safe places. As the crime rate drops new businesses rent more spaces as people are not afraid to move around in the area. The problem in public safety technologies comes from the fear of misuse. The constantly growing amount of surveillance and facial recognition capable technologies make people feel like they are constantly monitored. On the other hand, these technologies can track and recognize criminals in the crowd but that also means that the tracking applies to all the citizens.

Public health Smart initiatives can generate significant ROI for the cities. Nevertheless, only some of the cities have adopted these technologies in the public health sector. In addition to positive ROI figures, these technologies can also save lives. The main benefits of public health initiatives are increased health and well-being of the citizens, better response time in emergency services and, decreased mortality and morbidity. The problem with public health services is that not all the cities consider it as important and health services may be outsourced to the private sector. The positive side in this is that the private sector is also interested in the use of new technology and the city can offer joint projects with the private sector so these can be used by everybody. [Celi et al. 2019]

3.2.5   Governance and Funding

Strengths	Weaknesses
• City workers gain productivity • Increases city transparency • Smoother and faster processes which liberate workers to do other tasks • Highest total ROI	• Citizens adopt digital systems slowly • Elderly people find it hard to use digitalized city systems • Software bugs and traffic on sites can crash the whole system • Cities adopt slowly digital payment systems
Opportunities	Threats
• Attracts new businesses • Increases the city reputation • Reduces paper which has a positive impact on the environment	• High cybersecurity vulnerability • Cyber-attacks can crash the whole system and endanger city inhabitant's private information

Table 7 SWOT matrix of Governance and Funding

Table 7 shows the SWOT matrix made from Governance and Funding market area. Governance and Funding initiatives have the best overall ROI compared to other urban ecosystems. Even the cities which are on the implementer or advancer stage see moderately good ROI figures. The main benefits include gained productivity for city workers, more transparent city systems, improved reputation of the city, more engaged citizens and, the attraction of new businesses. If the city systems are changed to digital ones the citizens can, for example, fill out tax filings on the internet which erases errors and makes the whole process faster.

Even though e-Governance brings great ROI the cities have been slow to adopt digital systems. The problem with digital systems is that not all citizens especially elderly people know how to use them. Because of this there must be a normal system in use at the same time and running two systems at the same time brings more expenses for the city. However, as more citizens learn how to use digitalized city systems the old systems can be taken down. In addition, new systems must be able to handle all the traffic on the app/sites, or else the servers might crash.

Cybercriminals have always been interested in people's private information and one of the best places to find all the people's private information is government or city databases and therefore these sites must be strongly protected. Strong protection of the sites brings more expenses for the city. [Celi et al. 2019.]

3.3   Summary of the vertical analysis

The Swot analysis of the verticals shows that Smart technologies can have a large impact on the everyday life of the inhabitants in the city. There is not one clear market area which is the best to go to. Mostly the cities in different stages of hyperconnected ranks are interested in different things. Moreover, cities have social and political differences that change the interests even more.

First, the cities' infrastructure must be ready so that the Smart technologies can be implemented into the city. Without proper infrastructure in IT and telecommunications, it is impossible to even try to implement Smart technology into the use of inhabitants. Mostly this is because Smart technologies and IoT sensors do need a connection to each other.

The widespread availability of 5G is one of the preconditions that the cities must overcome before Smart technologies can get to full potential. The benefits of 5G networks are not going to be visible only in one market area, but in all market areas as a way to connect everything and start the implementation of Smart technologies in the city.

City stage	Public transit	Traffic management	Water	Waste & Environment	Energy & Electricity	Public Safety	Public Health	E-governance
Leader	5.3%	4.4%	5.2%	5.2%	4.3%	4.5%	5.6%	5.6%
Advancer	2.5%	2.9%	2.2%	2.6%	2.6%	2.5%	2.9%	3.6%
implementer	1.5%	2.0%	0.8%	2.0%	1.8%	1.5%	1.9%	2.6%
All	3.4%	3.3%	3.1%	3.5%	3.2%	3.1%	3.9%	4.1%

Table 8 Overall ROI in Smart Market Comparison [ESI, 2019]

For implementer cities, the best area to start the implementations of Smart technologies is the Mobility and Transportation area. This area has the most available data from the projects which have been completed in the Advancer or Leader cities. However, as the cities do have differences in areas of interest the starting point is not always the same. Table 8 shows the Overall ROI in smart market comparison. The ROI figures are taken from the study made by ESIthoughlab (2019) The E-governance initiatives have the best total ROI. The table also shows the average ROI differences for cities in different stages. The ROI grows as the cities can utilize more Smart technologies and progress in stages.

4   Analysis of the Market Potential in European Cities

In this chapter, Smart technologies market areas in nine different European cities in different stages of hyperconnected city rankings are analyzed. The analysis is made according to the conceptual framework which can be found in the literature part of the study. All the data for the analysis was taken from the hyperconnected city database. The Data is not updated all the time so some of the information might be from 2019 or older.

4.1   The market factors

The market was identified in the market segmentation and SWOT analysis. The best way to identify market potential in this study is to use already existing market factors in the database. Hyperconnected cities database and report were provided to be used in this study and the key metrics used in the analysis were picked from these sources.

The first thing in the analysis is the baseline information of the city. Baseline information consists of the population in the city, the city's rank in the hyperconnected cities ranking in the database and which stage the city is on, the situation of the Smart market in the city, GDP of the city, operating budget, and the availability of 5G. Especially the availability of the 5G might have changed since 2019 because of the rapid deployment of 5G networks recently. The market is sorted into two stages which are advanced or emerging

The second part of the analysis is about the city's identified risks in the Smart project's implementation identified by the city officials, current technologies employed by the city, current situation and interest in Data and analytics, and IT/telecommunications infrastructure. These are important because implementing Smart technologies into cities with undeveloped infrastructure is much harder than into cities with advanced infrastructure. The data analytics stage tells the stage in which the city is now considering Data utilization. Data initiatives are sorted into four different stages in the database. Stage 1 is the most undeveloped and stage 4 is the most advanced stage. The main challenges are important because those must be considered when thinking about new Smart initiatives.

The third part is the main part of the analysis. All the five different market areas of the Smart cities are ranked from best to worst. Furthermore, the most interesting area's current initiatives are investigated and analyzed. The current initiatives are sorted in the database into five different stages which are Not pursuing, Planning, Piloting, Partial deployed, and Widescale deployment. The Partial and Widescale deployed initiatives have reports of what the ROI has been after the launch of the project. Example pictures of the database can be found in Appendix 2.

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4.2   Copenhagen

Population	1.3 million
Hyperconnected Cities Ranking	7th, Leader
Market	Advanced
City GDP	88.04 billion $
Operating Budget	5.69 billion $

Picture 1 Copenhagen City

5G availability: Pre-release

Table 9 Baseline Data of Copenhagen

Copenhagen is the capital and the largest city in Denmark. It is the 7th most advanced city in the hyperconnected city ranking list. All the current technology and IT-infrastructure initiatives in Copenhagen are in stage 2 or over so in terms of data analytics it is on a rather advanced stage compared to other cities. Data is for example used to constantly improve city operations and offered to stakeholders for further use. Some of the technologies employed now are Artificial Intelligence, Blockchain, Robots, and Drones. Furthermore, the 5G network is in the pre-release stage and is going to be available soon.

The main challenges in the implementation of Smart projects identified by the city officials are Attracting and Retaining business, Business and Financial constraints, and Inadequate/Obsolete infrastructure. These challenges are not insurmountable and can be fixed with making the Smart projects more attractive to investors by developing the infrastructure especially the 5G network.

Market	Current priority level	Project start	Investment change rate	Average ROI
Environment and Sustaina-bility	Medium	>5 years	+25%	5,2%
Governance and Funding	Medium	2-5 years	+0%	5,6%
Public Safety and Health	Medium	>5 years	0%	5,1%
Mobility and Transportation	Low	>5 years	+11%	4,9%
Energy and Water	Low/Not a Priority	2-5 years	-6%	4,8%

**Table 10** Smart City Market Analysis Copenhagen

Copenhagen's interest in new Smart technology initiatives is rather low. The main reason for this is that most of the city segments have already widescale/partial deployment in Smart technologies and the projects have been running for over five years now. Most of the interest now goes towards Buildings, public spaces, talent, and education. As it turned out in the SWOT analysis Leader cities have higher ROI than the Implementer or Advancer cities and almost all the initiatives which have been deployed in Copenhagen have seen moderate or large positive ROI.

Now the most favorable Market in Copenhagen would be to offer help in making the infrastructure better and deployment of 5G to a widescale use. Undeniably, the existing systems also need continuous improvement and Copenhagen would suit as a testing platform for new systems. As the Smart technologies are so widely used in Copenhagen it is also a perfect place to look for an example. Of course, the differences in cities must be considered and differences can change the ROI figures but most of the systems could work the same way in other cities.

As a conclusion it can be said that for new investing areas it would be best to wait for some time so that new technologies are developed. Copenhagen is one of the best places in Europe to deploy the State-of-the-Art technologies so that there can be an example for other cities to see the full benefit of the Smart City technologies.

4.3   Helsinki

Population	0.65 million
Hyperconnected Cities Ranking	17th, Leader
Market	Advanced
City GDP	33.61 billion $
Operating Budget	4.86 billion $

Picture 2 Helsinki City

5G availability: Commercial
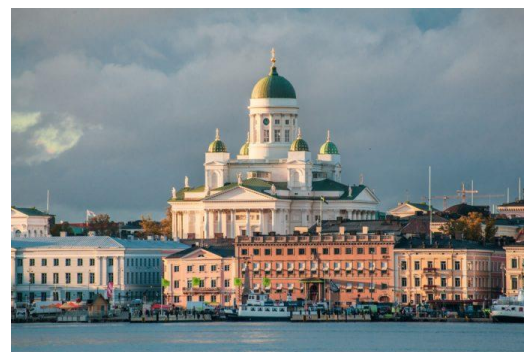
Table 11 Baseline Data of Helsinki

Helsinki is the capital and the largest city in Finland. In terms of a Smart City, Helsinki is one of the more advanced cities. Helsinki has already deployed some Smart technologies into everyday use. These are for example Artificial Intelligence, Facial Recognition, Blockchain, etc. As for the use of data Helsinki is also having many initiatives progressing now. Their data collection is already on Stage 4 which is a good sign because advanced data collection is important when making a city Smart and it makes further data utilization easier. Moreover, the 5G network in Helsinki is already commercially available.

The main challenges that the Helsinki city officials have identified in the implementation of Smart projects are Climate change and pollution, Elevated physical and digital security risks, Income inequality and social inclusion, and Significant talent and skill gaps. The procurement methods in new technology are Outsourcing to consultants and partnering with technology providers. Helsinki could provide a good testing platform for new state-of-the-art technologies in the same way as Copenhagen. Furthermore, Helsinki has a very high interest in Data and analytics tools which can develop the way that the city handles and utilizes its Data.

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Market	Current priority level	Project start	Investment change rate	Average ROI
Environment and Sustaina-bility	High	2-5 years	+33%	5,2%
Governance and Funding	High	1-2 years	+17%	5,6%
Public Safety and Health	High	2-5 years	+12%	5,1%
Energy and Water	Medium	2-5 years	+6%	4,8%
Mobility and Transportation	Medium	>5 years	+20%	4,9%

Table 12 Smart City Market Analysis Helsinki

Now the most potential market to go into in Helsinki is the Environment and Sustainabil-ity. Its current priority level and the investment are just going to grow towards it with a change rate of +33%. Helsinki has already deployed some technologies in this area. Partially deployed now are the optimization of waste collection, Real-time air monitoring system, and real-time water monitoring system. All these projects have seen a positive ROI. Funding comes from Federal or Provincial support, and some projects have con-sumption-based monetization.

The second interesting market in Helsinki is Governance and Funding. The investment change rate is +17% which is rather high, and the average ROI is the highest compared to other market areas. The funding for governance and funding in Helsinki comes from concession, crowdfunding, and vendor financing. The user penetration rate of digital commerce in Finland is 84.53% so the users are not unfamiliar with digital systems.

The other market areas are interesting too but the most fascinating are the two men-tioned above. Some of the advanced technologies have already deployed into the Mo-bility and Transportation section of the city. The market in Helsinki is growing all the time which should make the city officials invest in new initiatives rather easily. As the ROI is high, some private investors could also have interest in the Smart initiatives in Helsinki

4.4   Milan

Population	1.37 million	
Hyperconnected Cities Ranking	23rd, Leader	
Market	Advanced	**Picture 3** The Milan Duomo cathedral
City GDP	71.75 billion $	
Operating Budget	3.74 billion $	5G availability: Pre-release

Table 13 Baseline Data of Milan

Milan is the second-largest city in Italy. It is the economic center of Italy and Borsa Italiana S.p.A which is Italy's only stock exchange is situated there. Milan's hyperconnected city ranking is 23rd and it is third last of the leader cities. Data analytics are in a moderately high stage and most are progressed to stage 2 or 3. The city employs for example Artificial and Cloud-Based technology. The procurement methods for data technology are buying and licensing the technology and partnering with technology providers.

The identified main challenges in the implementation of Smart projects are Elevated Physical/Digital security risks, and High crime rates, and low public safety. These challenges can be solved by employing more Smart technologies into the city's infrastructure. 5G technology in Milan is still in its pre-release stage but should be available soon. The total infrastructure and data usability are not so advanced compared to the Helsinki or Copenhagen but as it is in a moderately advanced stage it should be easy to deploy new Smart technologies into the use of Milan.

Market	Current priority level	Project start	Investment change rate	Average ROI
Governance and Funding	Medium	2-5 years	+67%	5,6%
Environment and Sustaina-bility	Medium	2-5 years	+33%	5,2%
Public Safety and Health	Medium	>5 years	-30%	5,1%
Mobility and Transportation	Low	>5 years	-23%	4,9%
Energy and Water	Low/Not a Priority	2-5 years	-33%	4,8%

Table 14 Smart City Market Analysis Milan

The most interesting near-future market potential in Milan is in Governance and Funding area. Projects have started 2-5 years ago, and the investment change rate is +67%. As the Governance and Funding has the best ROI amongst these market areas the interest towards it is even greater. Now Governance and Funding initiatives progress stage are at partial or widescale deployment and most of those have seen positive ROI, only digital land-use and building permitting has had small negative ROI. The benefits have been the attraction of new business, increased compliance, and gained productivity of city workers. Most of the projects have been funded from city budget or supported by state and some projects have used revenue sharing or user fees.

The other interesting area is the Environment and Sustainability. Most of the projects are in a planning stage and already deployed projects have seen moderate or large positive ROI. The projects have been funded mostly with federal support. Since the projects are still at a planning stage it can be easy to involve in those as a supporter.

Milan city officials do not show almost any interest in the other three areas. There is some interest in Public Safety and health initiatives, but the investment change rate is negative at -30% which shows that the investments are decreasing.

4.5   Brussels

Population	1.2 million	
Hyperconnected Cities Ranking	39th, Advancer	
Market	Advanced	
City GDP	77.03 billion $	
Operating Budget	0.85 billion $	5G availability: Not availabe

Picture 4 City of Brussels

Table 15 Baseline Data of Brussels

Brussels is the capital city of Belgium and at the same time the capital city of the European Union. Brussels is the first Advancer city in the analysis. Its hyperconnected city rank is 39th but its market is in an advanced stage. The operating budget is much lower than in the Leader cities and one of the main challenges identified by the city officials to implement Smart projects is budget and financial constraints. The other challenges are attracting and retaining businesses, and significant gaps in talents and skills.

Technology and data initiatives are still in the developing stage and only managing data and collection of data are in stage 3. Other initiatives are still in stage 1 or 2. However, Brussels city officials are having Data and Analytics on a high priority so the systems should be developed further in the coming years. Some technologies employed by the city include Data warehousing, Cloud-based technologies, Digital assistants/chatbots, and IoT sensors. 5G is not available in the city and the projects are paused because of radiation restriction and the city has had some problems in the past when trying to offer high-speed wireless connections for its inhabitants.

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Market	Current priority level	Project start	Investment change rate	Average ROI
Mobility and Transportation	High	<12 months	+60%	2,7%
Governance and Funding	Medium	<12 months	+67%	3,6%
Environment and Sustaina-bility	Not a priority	<12 months	+50%	2,6%
Public Safety and Health	Low	1-2 years	-20%	2,7%
Energy and Water	Low/Not a priority	1-2 years	0%	2,4%

Table 16 Smart City Market Analysis Brussels

The highest interest in Brussels is towards Mobility and Transportation. Current planned initiatives include bike lane traffic signals, Mobility as a service app, Smart parking app, intelligent traffic signals, and vehicle to infrastructure connectivity (V2X). Its current priority level is high, and the investment change rate is +60%. Consequently, the interest and investments are just going to grow in the future. Some of the already seen benefits have been decreased accidents, lowered costs, and reduction in emissions. The funding has mostly come from federal support, but some expenses have also been covered with consumption-based user fees.

Another compelling market is the governance and funding the priority level of which is just medium, but the investment change rate is very high at +67%. Initiatives have been funded from the city budget and most of the projects have been for the different departments of the city. The ROI has been positive for most of the projects and the benefits include the Attraction of new residents and tourists, an increase in compliance, and Time savings for all stakeholders. Even though the priority level for Environment and Sustainability is low now, the investments are going to grow +50% in the future which makes it also an interesting area to focus on.

The other areas in the markets are not compelling for the Brussels city officials so those can be put under scrutiny to see if the situation changes in the coming years. In the end, Brussels is advancing in the Smart city projects but the pause in 5G projects makes the full potential of Smart city hard to reach.

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4.6   Vienna

Population	1.87 million	
Hyperconnected Cities Ranking	50th, Advancer	
Market	Advanced	
City GDP	91.96 billion $	
Operating Budget	15.40 billion $	5G availability: Not available

Picture 5 City of Vienna

Table 17 Baseline Data of Vienna

Vienna is the cultural, economic, and political center of Austria. It is also the nation's capital city. Its rank of 50 puts it into the middle of the hyperconnected cities ranking list. In terms of Smart technologies, it is one of the Advancer cities and even though it is in the middle of the list the market is still on an advanced stage. The main challenges identified by the city official are attracting and retaining businesses, high congestion and limited mobility, high crime rates and low public safety, and significant gaps in talent and skills.

Vienna's city officials' interest in data and analytics is only Medium, but the interest in IT and telecommunication systems is High. Most of the initiatives are already on stage 2 or 3 and only data prediction and protection are on stage 1. The city has already implemented some new technologies, which are for example Artificial Intelligence, Facial recognition, and IoT sensors. 5G is not yet in operation but should be available in the coming years.

Market	Current priority level	Project start	Investment change rate	Average ROI
Mobility and Transportation	Very High	<12 months	+20%	2,7%
Governance and Funding	High	1-2 years	0%	3,6%
Public Safety and Health	High	<12 months	0%	2,7%
Environment and Sustaina-bility	Medium	<12 months	0%	2,6%
Energy and Water	Medium	1-2 years	0%	2,4%

Table 18 Smart City Market Analysis Vienna

The only area which is having a positive change in investment change rate is Mobility and Transportation. None of the initiatives have yet progressed to widescale use and are only on a partial deployment, piloting, or planning stage. The projects which have been partially deployed have mostly received positive ROI. Only digital public transit payment systems have brought small negative ROI. The funding has been completely private, and the state does not support Mobility and Transportation initiatives. The initiatives have decreased the travel times and increased transit ridership.

Governance and Funding is on a high priority for city officials, but the investments are going to stay the same in the future. The only initiative which is deployed into a widescale use is Digital Payments systems and its ROI has been positive but only in small amounts. Similar to Mobility and transportation, Governance and Funding initiatives are mostly on planning or piloting stage. Likewise, the Public Safety and Health initiatives are in a planning or piloting stage. Only a couple of initiatives have been partially deployed and those have seen some positive ROI but mostly it is too early to tell what the ROI is going to be.

In terms of market opportunities, Vienna is dull. The initiatives have not yet shown enough positive ROI for the city officials and investors so they would get more interested in Smart initiatives. However, as some of the projects get to widespread use the situation can change rapidly and the case company should keep an eye on the changes in Vienna.

4.7   Prague

Population	1.28 million
Hyperconnected Cities Ranking	71st, Advancer
Market	Emerging
City GDP	44.65 billion $
Operating Budget	2.30 billion $

Picture 6 Prague city center

5G availability: Pre-release

Table 19 Baseline Data of Prague

Prague is the capital and the largest city of the Czech Republic. It is the last of the Advancer cities in this analysis and its Smart technology market is only just emerging. The main challenges in the Smart projects identified by the city officials are constraints in budget, gaps in talent and skills, and weak economic and employment situation. None of the Data or IT and telecommunications projects have not progressed to the stage 3. Most of the projects are still in stage 2 and the priority is only medium. Therefore, it seems that the city of Prague is not yet interested in the newest Data and IT technologies.

The digital technologies employed by the city are for example Data warehousing, Cloud-based technology, and open-source data platforms. IoT sensors have not yet been implemented in the city but 5G is in its pre-release stage and after it has been deployed taking the IoT sensors into use is going to be a lot easier. The only area which uses advanced technologies now is the Governance and Funding. The procurement methods have been to develop systems internally, licensing the technology, and partnering with technology providers.

Market	Current priority level	Project start	Investment change rate	Average ROI
Governance and Funding	Medium	1-2 years	+11%	3,6%
Environment and Sustaina-bility	High	2-5 years	0%	2,6%
Energy and Water	High/Low	1-2 years	+22%	2,4%
Public Safety and Health	Medium	2-5 years	-12%	2,7%
Mobility and Transportation	Medium	2-5 years	-20%	2,7%

Table 20 Smart City Market Analysis Prague

Even though Prague's total rank in Hyperconnected cities list is 71st, it is on a rather advanced state in all the Smart cities market areas. The reason why Prague's total rank is so low is that the Data and IT-infrastructure is on an undeveloped stage.

The most interesting market potential is in the Governance and Funding area. Even though the current priority level is only on a medium level the investment change rate is much higher than in the Environment and Sustainability. Some of the Governance and Finance initiatives have already been deployed and all of those have seen moderate or large positive ROI, and the other projects which have not yet been deployed are going through the piloting phase so the results should be available soon. The initiatives have already shown some benefits which are an Increase in city transparency, compliance, and gained productivity of city workers.

The Environment and Sustainability initiatives which are mostly funded by federal sup-port are having a high current priority level in the city of Prague. The investments towards are going to stay on the current level but government support makes it easier to start new initiatives. Although the Water priority level is low the priority level for Energy initia-tives is high. City of Prague city officials are very interested in the new Smart technolo-gies in the Energy market area and there is already some initiative on a partially deployed stage. As a whole, Prague is a very interesting market considering that their IT-infra-structure is not so developed and many of the Smart projects have already been de-ployed.

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4.8   Bratislava

Population	0.2 million	
Hyperconnected Cities Ranking	76th, Implementer	
Market	Emerging	**Picture 7** Bratislava City Center
City GDP	7.62 billion $	
Operating Budget	0.43 billion $	5G availability: Pre-release

Table 21 Baseline Data of Bratislava

Bratislava is the capital city of Slovakia. With the rank of 76 it is the first implementer city in this analysis. Their operating budget is rather low, and the main challenges identified by the city officials when implementing Smart projects are attracting and retaining businesses, inequality in income and social inclusion, and significant gaps in talent and skills.

The highest interest now goes towards the IT and telecommunications infrastructure. Bratislava's infrastructure is still so undeveloped that it must be built further so that the implementation of Smart technologies would be easier. The interest in Data and analytics is low and the city does not employ a great number of technologies. Some cloud-based technologies and IoT sensors are in use. However, data collection and extracting value from data are already on stage 3 so when the results from these are available the city official can notice the value of advanced data analytics. The 5G in Bratislava is already on the pre-release stage.

Bratislava's data and IT markets are very compelling. The growing interest in Data and analytics is opening a lot of business opportunities in the city. However, there is some time before the market is ready for advanced data tools and analytics.

Market	Current priority level	Project start	Investment change rate	Average ROI
Environment and Sustaina-bility	Medium	1-2 years	+43%	2,0%
Mobility and Transportation	High	1-2 years	-33%	1,8%
Energy and Water	Medium/Low	1-2 years	-17%	1,3%
Governance and Funding	Low	1-2 years	-14%	2,6%
Public Safety and Health	Medium	2-5 years	-42%	1,7%

Table 22 Smart City Market Analysis Bratislava

The most interesting market in Bratislava now is the Environment and Sustainability. Its current priority is medium which is lower than in Mobility and Transportation, but the investment change rate is much higher. All the initiatives which have been deployed partially have had positive ROI. The benefits have been decreased pollution and an increase in the efficiency of waste management and better water quality. The projects have been funded with city support and some projects have had private investors involved.

The interest towards Mobility and Transportation is high and there is a lot of projects on a planning or piloting stage. However, the investment change rate of -33% shows that the interest is going to come down in the future and even though the initiatives are on a planning stage does not tell that they are going to a piloting or deployment stage. These projects have been funded by federal support or from the local city budget. The investments have brought positive ROI for the city, but the ROI has been rather low. The low ROI can be explained by the fact that the Implementer cities ROI from projects is lower than in the more advanced cities.

The other market areas are all showing negative investment change rates and low priority for the city. The widescale deployment of 5G might be able to change that. Now the Bratislava's interest in new Smart technologies is decreasing so the best option would be to wait for a while and see how the priority levels are changing in the future. Fast changes can happen in the market especially when the Data and IT infrastructure progress to stage 3 and 4.

4.9   Sofia

Population	1.26 million	
Hyperconnected Cities Ranking	80th, Implementer	
Market	Emerging	
City GDP	19.12 billion $	
Operating Budget	0.64 billion $	5G availability: Pre-release

Picture 8 Alexander Nevski Cathedral in Sofia

Table 23 Baseline Data of Sofia

Sofia is the largest city in Bulgaria. It is also the capital city of the country. In terms of Hyperconnected Cities Ranking, it is the 80th city on the list. Its hyperconnected stage is Implementer and the market is still on an emerging stage. The priority level of Data and analytics is Medium and most of the projects have already progressed to stage 2 or 3. Only the Data protection is on stage 1. The city employs a great amount of technologies compared to other Implementer cities. These technologies are for example Artificial Intelligence, Facial recognition, Blockchain, etc. The procurement methods for the technologies has been to buy the technology or outsourced implementation to consultants.

The main challenges in the implementation of Smart technologies have been high congestion and limits in mobility, high crime rates, and low public safety, concerns towards public health, and significant gaps in talents and skills. The city's operating budget is rather low for overcoming these obstacles. Even though many of the technology and IT infrastructure initiatives are already advanced to stage 2 or 3 the infrastructure in Sofia is still very undeveloped. That might change with the release of 5G which is now on the pre-release stage.

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Market	Current priority level	Project start	Investment change rate	Average ROI
Public Safety and Health	High	1-2 years	+50%	1,7%
Mobility and Transportation	High	1-2 years	+36%	1,8%
Environment and Sustaina-bility	High	<12 months	+33%	2,0%
Governance and Funding	Medium	1-2 years	+45%	2,6%
Energy and Water	Low	1-2 years	+25%	1,3%

Table 24 Smart City Market Analysis Sofia

The interest in Smart technologies in Sofia is very high in almost all the market areas and all the areas are having rather large positive investment change rates. All the initiatives have been started in recent years and the growth is still strong which is a good sign for the future of these Smart technology markets.

Now the highest priority level and investment is in Public Safety and Health. A couple of the initiatives have already seen partial deployment and from those, the ROI has been small or moderate positive. Other initiatives are mostly on the piloting stage. The city or government has not funded these projects rather the funding sources have been crowd-funding, revenue sharing, and social impact bonds. The benefits form these initiatives have been the attraction of new businesses, residents, and tourists.

The Mobility and Transportation initiatives are all in the piloting or planning stage except for digital public transit payment systems and mobility as a service app that has been deployed partially. The ROI from these has been moderately positive. The city has not funded these projects either and the investment structure is similar compared to the Public Safety and Health initiatives.

Sofia's Smart technology market is rather compelling. The high growth investments and the high current interest in these technologies make this city worth considering. Because the market is still in the developing stage it should not be hard to get involved in initiatives that are on the planning or piloting stage.

4.10 Kiev

Population	2.9 million	
Hyperconnected Cities Ranking	93rd, Implementer	
Market	Emerging	
City GDP	45.91 billion $	
Operating Budget	14.08 billion $	5G availability: Not available

Picture 9 Kiev City Center

Table 25 Baseline Data of Kiev

Kiev is the capital city of Ukraine. It is the Ukraine industrial, technological, and cultural center. With the rank of 93, it is the last city in Europe on the hyperconnected cities ranking list. Its hyperconnected stage is Implementer and the market is on an emerging stage. The operating budget of the city is high compared to the other Implementer or Advancer cities. The city officials have identified risks when implementing Smart projects and these are high rate of crime and low public safety, inequality in income and social inclusion, large population growth, and significant gaps in talent and skills.

Currently, in terms of technology and IT infrastructure, Kiev is 94th of the 100 ranked cities. However, the interest in Data and analytics is very high. Most of the Data and analytics initiatives are on Stage 1 or 2. The procurement method has been to outsource the implementation to consultants. The city does not employ so many modern technologies now. Some that it already employs are IoT sensors and Public Wi-Fi networks. 5G is not yet available in Kiev and there is no information available when it is going to be. As a market, Kiev has much interest in Data and IT technologies.

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Market	Current priority level	Project start	Investment change rate	Average ROI
Public Safety and Health	Very High	2-5 years	+23%	1,7%
Environment and Sustaina-bility	Very High	<12 months	+12%	2,0%
Governance and Funding	High	1-2 years	+10%	2,6%
Energy and Water	Medium	1-2 years	+46%	1,3%
Mobility and Transportation	Medium	2-5 years	+19%	1,8%

Table 26 Smart City Market Analysis Kiev

The Smart technologies market in Kiev is growing at a fast pace. All the market areas are having a positive investment change rate. The ROI is rather low but that is because Implementer cities have low ROI. However, as the investments grow and Kiev goes towards Advancer state so does the ROI grow at the same time.

Now the best market area to go to is Public Safety and Health. The priority level is very high, and investments are continuing to grow. The initiatives which have already been deployed have brought the city decrease in violent crime, improved the reputation of the city, and increased the citizen well-being. The initiatives have been mostly funded with federal support and crowdfunding.

Another market area with very high priority is the Environment and Sustainability. The projects are rather new considering that most of those started under 12 months ago. The only initiative which has progressed to widescale deployment is Optimization of waste collection and it has had a large positive ROI. The Governance and Funding is also showing a lot of interest in city officials of Kiev. Most of the initiatives have progressed to partial or widescale deployment. All the initiatives have had positive ROI except distributed government which has had small negative ROI.

The city of Kiev has an interest in Smart technologies. The growing investments and high priority of market areas make it easy to get to the Kiev's market of Smart technologies.

4.11 Summary of City analysis

The cities differ from each other greatly. Most of the difference comes from the maturity level of the technologies already in the use of the cities. Some of the cities have already implemented a great number of Smart technologies and others are still at the starting stage. Since the cities have had different starting points and interests some technologies currently have a higher prevalence of the cities.

Because of the different interests from the start, there is not a certain point of interest for all the cities. The results from the analysis show the current go to market in the cities. As the world changes rapidly especially seen in what Covid-19 pandemic caused to the world, the cities and its inhabitants' interest can change fast. It is impossible to say where the interests of the city officials and society is going in the future, but the interests of the Leader cities can give some direction for the Advancer and Implementer cities.

But as said in the introduction of the study and seen in the analysis, cities do need more developed systems and technologies to control the operations in different areas. The benefits of the Smart technologies are clear and if the cities can take the full potential out of these technologies it makes those even more profitable. So, the cities should implement more of these technologies so they could climb up the ranks in Hyperconnected cities ranking list and get to the Leader stage in which the ROI and benefits are best.

One area which stands out in the Leader and Advancer cities is the Governance and Funding. It is ranked high in most of these cities. Likewise, Environment and Sustainability is high in the interests in many of the cities. The reason for this is the increasing debate around environmental issues impacting the lives of everybody.

5   Proposal of the most lucrative near-future market opportunities for the case company

In this chapter, the proposal of the most lucrative market opportunities is introduced. The proposal is based on the findings in the analysis part and divided into two different parts which are proposal concerning the verticals and the cities. Additionally, a short description of the potential in different cities is included.

5.1   Verticals

The findings of the analysis are not showing any vertical which would stand out clearly, rather all the verticals have good sides. In short, the Governance and Funding has the best ROI figures and brings time savings for the city workers, Mobility and Transportation initiatives have the most data available, Environment and Sustainability can help in the fight against climate change, Public Safety and Health benefit the overall health of the inhabitants and help fight crime in the unsafe cities, and Energy and Water initiatives improve public health and reduce the use of electricity. These were just short descriptions of the main benefits of the verticals as there are more benefits which can be seen in the SWOT analysis.

While the verticals have good sides, they also have bad sides, and thus picking the best is not just comparing the bright sides. Furthermore, in most cases Smart initiatives have positive impact and ROI, and thus the benefits are larger than the weaknesses. Based on the findings of this thesis, it is clear that the Smart technologies are becoming more common in the future, and cities have an interest in these. In addition, the use of 5G technology is going to make the use of Smart technologies and sensors even more efficient. Admittedly, Smart technologies can work without 5G but getting these to the full potential requires developed IT-infrastructure which includes 5G, and advanced Data analytics. The best use of 5G in the cities would be to utilize it to link everything in more reliable and faster connections.

Rank	Market area	Stage of the city which benefits the most
1.	Governance and Funding	Leader
2.	Mobility and Transportation	Implementer/Advancer
3.	Environment and Sustainability	All/Leader
4.	Public Safety and Health	All
5.	Energy and Water	All

Table 27 Smart city market areas ranked from best to worst

Table 27 shows the final rankings of the Smart city market areas. Based on the findings in the vertical and city analysis the best market to go to is the Governance and Funding. This does not quite apply to all the cities but the cities that are already on the leader stage in the Hyperconnected ranking get the most benefit out of this. The reason why Governance and Funding is the best market to go to is that its main benefits include the best ROI figures, the initiatives do not need particular infrastructure and therefore these are rather cheap and easy to carry out compared to other initiatives, it saves time from the city workers, and many cities have a high interest towards it. The second best go to market is the Mobility and Transportation. This is because Mobility and Transportation is the most common market area which already utilizes Smart technologies, it has the most data available from the past initiatives, and the easiest place to start the use of Smart technologies in undeveloped cities. The biggest weakness of Mobility and Transportation initiatives comes from the high cost of the projects.

The third best go to market is the Environment and Sustainability. Most of the advanced cities have a high interest in it and it is a topic that is growing interest all the time because of climate change. These initiatives can also tell people that the city is responsible and acts against climate change. The benefits can be seen in the cities on all the Hyperconnected stages, but the Leader cities get most out of these. The fourth market is the Public Safety and Health. These initiatives do have many benefits but the cities interest towards these is rather low. Not all the cities have sophisticated public healthcare, and public safety initiatives are only popular amongst the cities that have high rates of crime which is only a small part of the cities.

The least interesting market area is the Energy and Water. Most of the cities do not have any/low interest in these. As a whole Energy and Water is not interesting, but there are interesting initiatives in this market area. One initiative which has a great number of benefits is the use of smart streetlights. Smart streetlights provide a platform for other sensors, so this benefits in more ways than just savings in electricity. Moreover, the Smart streetlights can be used as a 5G base stations which makes it even more interesting.

One market area that was not taken into the analysis but is interesting and it was described in the city analysis is the Technology and IT-infrastructure of the cities. This should be the starting point when developing the cities. As the advanced use of Data and analytics can benefit the cities in many ways. All in all, Smart technologies are a very attractive place to invest in. The market and technology are evolving all the time, so nobody knows where it is going from here. With this proposal, the case company should have a better idea in which direction to go in the near-future market in the Smart cities. As the market is growing rapidly, my suggestion for the case company would be to take quick action and start investing in these markets as fast as possible.

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5.2   Potential in different cities

The differences in the cities are not clear and do not have any specific source where these would come from. As the cities have political, geographical, socio-economic, and development differences it cannot be said that what works in some cities, works in all the cities. It is impossible to say for certain what the cities want with small samples as taken into this study. However, some potential in the cities was uncovered even though the study mainly aimed to study the verticals.

The leader cities show many similarities amongst them. As the Smart initiatives have existed for a longer time the current interests are already in the future technology. As said before the best use of Leader cities would come from the state-of-the-art Smart initiatives. As the IT-infrastructure and Smart initiatives are in the most developed in the leader cities, the new initiatives should be easy to perform. Furthermore, the leader cities would be a perfect place to conduct more studies about the past initiatives that have succeeded and failed as the Leader cities have most of the data. As a summary, it is clear that the Leader cities show the way for the more undeveloped cities, but it is not guaranteed that all the pilot projects succeed and thus some failures are expected and unavoidable.

It is harder to predict and say what the Advancer and the Implementer cities want or are interested in. The analysis does not show any major similarities amongst the cities taken into this study. Mostly it seems that the cities have taken different ways and steps when implementing Smart technologies. The best potential in the cities with undeveloped IT-infrastructure and the use of data would be to help the cities to develop IT-infrastructure and the stage of data analytics further. Advanced data analytics could boost the cities progress and guide the processes towards data-based decision making, and improved IT-infrastructure makes Smart technology implementation easier. Although some cities were ranked as Advancer or Implementer cities, they have had some successful and advanced Smart initiatives. These should be also considered when studying past initiatives.

The diversity of the cities makes it hard to see where the potential is. The deeper dive into the reasons behind the differences and similarities would be preferable to consider when going into the market of Smart technologies in a new city.

5.3   Summary of Proposal and Future Research suggestions

The Smart cities are a compelling market area. As the cities continue to grow and the technologies advance Smart technologies are going to be even more present in the development of the cities. It is hard to predict the true usage of Smart technologies and devices in the future but now, according to the findings made in this study the best Smart city verticals to focus on are as follows:

1. Governance and Funding

2. Mobility and Transportation

3. Environment and Sustainability

4. Public Safety and Health

5. Energy and Water

On the other hand, cities do have many differences amongst them so it cannot be said for certain that all the cities are interested in the same verticals. However, it can be said that some findings which were obtained in this study and would be suggested to focus on cities are:

- Use Leader cities as a testing ground for state-of-the-art Smart initiatives

- Help Implementer and Advancer cities develop better IT-infrastructure

- Offer advanced Data analytics tools and systems for cities

However, the whole world is at a turning point because of the COVID-19 pandemic and the uncertainty about the future is visible everywhere. Nobody knows how these new situations that have arisen are going to change our life. The Smart market needs more research to be made, and my suggestions for future research would be to make studies about:

which were analyzed with SWOT were in this study: Mobility and Transportation, Energy and Water, Environment and Sustainability, Public Health and Safety, and Governance and Funding.

The cities were chosen keeping in mind the aim of this study and they had to fulfill three criteria determined with the case company representative. Firstly the cities had to be situated in Europe, secondly, the cities had to be on different Hyperconnectivity stage because SWOT analysis showed that the main difference in cities comes from that, and thirdly the aim was to research smaller cities thus the major cities in Europe were left out of this study.

After the analysis, the third step could be conducted. The aim was to evaluate the findings of the study and build a proposal for the case company. The findings from the analysis of Data 1 & 2 were considered in the proposal. With the proposal, the company should have a lower risk when entering the Smart city markets. Furthermore, the company should have a better understanding of what to consider when investing in the different market areas in Smart cities. As the Smart cities are rather new business area there is not so much data and results available, and some of the inputs are just estimates from the cities, the findings in this study should be taken as directional advice.

6.2   Recommendations concerning practical next steps for the case company

More data must be collected before the full potential of Smart technologies and IoT sensors in the cities can be seen. The first recommendation is that the case company should establish a research and sales team which only studies the potential new markets and technological development in the cities. This team could provide more detailed information about the cities' differences and where these come from. Furthermore, as the case company is a telecommunications technology provider the team could help the cities to develop more advanced IT-infrastructure since most of the cities need more developed technological infrastructure to handle the huge amount of data that Smart devices create.

The second recommendation is that already deployed initiatives in the cities should be assessed in a more detailed way so that the same mistakes made in past initiatives

would not happen again. Most of the initiatives researched in this study were successful and the failed projects were not investigated. The research of failed projects combined with the findings in this study should give a clearer picture of what to do in future initiatives.

The third recommendation is that the case company in cooperation with other technology companies should start pilot projects in the Leader cities with state-of-the-art technology. The leader cities are those which show the way to more undeveloped cities. Additionally, the leader cities have more developed IT-infrastructure to handle the state-of-the-art technological initiatives. The results from these initiatives could be then taken into the advancer and implementer cities. Leader cities are also more familiar with Smart technologies as these have existed there for a longer time.

6.3   Evaluation of thesis credibility

In this chapter, the credibility of the thesis is evaluated. The literature study was broad and comprehensive so that the framework for this study was thorough. All the data used in this study were from sources provided either from the case company or from academic records. Combining different sources and results from various studies makes the findings more reliable.

The analysis would have had similar findings if it would have been conducted by anybody. Personal opinions were not used when making the analysis or conclusions in this study and if personal opinions were used then it was mentioned clearly. Most of the data were collected and analyzed in recent years and thus the findings should also be up to date during the completion of this thesis.

References

Celi, L. et al. 2019. Building a Hyperconnected City-report. [PDF] <file:///C:/Users/alecb/OneDrive/Tiedostot/Opiskelu%20yms%20projektit%20TuTa/Opinn%C3%A4ytety%C3%B6/Materiaalit%20Nokia/ESITL_Building-a-Hyperconnected-City_Report.pdf>. [Accessed 15.4.2020]

Chandler, S. 2020. How Smart Cities Are Protecting Against Coronavirus But Threatening Privacy. Forbes Magazine. [Online] Available at: <https://www.forbes.com/sites/simonchandler/2020/04/13/how-smart-cities-are-protecting-against-coronavirus-but-threatening-privacy/amp/> [Accessed: 14.4.2020]

Curran, C. 2020. What Will 5G Mean for the Environment?. [Online] Available at: <https://jsis.washington.edu/news/what-will-5g-mean-for-the-environment/> [Accessed 25.3.2020]

ESIthoughtlab. About the Hyperconnected Cities Research Program. 2020. [Online] Available at: <https://hyperconnectedcities.esithoughtlab.com/about-rankings/#about-the-project> [Accessed 1.4.2020]

Esithoughtlab. Hyperconnected cities data navigator. 2020. [Online] Available at: <https://hyperconnectedcities.esithoughtlab.com/city-rankings/> [Accessed 15.5.2020]

European Commission Smart Cities. 2017. [Online] Available at: <https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en#what-are-smart-cities> [Accessed 27.3.2020]

IoT-Opas yrityksille, Uutta liiketoimintaa ja parempia päätöksiä. Telia Finland Oyj. 2017. [Online] Available at: <https://image.asiakas.telia.fi/lib/fe8b137374640c747d/m/1/3a905214-835a-4eae-b9b7-a73700b2abc8.pdf?utm_source=B2B_eng&utm_medium=email&utm_campaign=dl_iot_opas&utm_content=https%3a%2f%2fimage.asiakas.telia.fi%2flib%2ffe8b137374640c747d%2fm%2f1%2f3a905214-835a-4eae-b9b7-a73700b2abc8.pdf&sfmc_s=251257648> [Accessed 21.4.2020]

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ISO. What are Smart Cities?. 2020. [Online] Available at: <https://www.iso.org/sites/worldsmartcity/> [Accessed 1.4.2020]

Karpinski, R. et al. 2019. The Digital Smart City Opportunity. 451 Research LLC. [PDF] Available at: <file:///C:/Users/alecb/OneDrive/Tiedostot/Opiskelu%20yms%20projek-tit%20TuTa/Opinn%C3%A4ytety%C3%B6/Materiaalit%20Nokia/451Re-search%20on%20Smart%20City%20opportunity.pdf> [Accessed 21.4.2020]

Koski, H. et al. 2017. Avoimen datan hyödyntäminen ja vaikuttavuus. Helsinki, Valtioneuvoston kanslia. [Online] Available at: <https://tietokayttoon.fi/docu-ments/10616/3866814/40_avoimen+datan+16032017.pdf/0444467d-5400-4f0c-8728-2447cef039ad/40_avoimen+datan+16032017.pdf?version=1.0> [Accessed: 3.4.2020]

Mitä Smart City tarkoittaa? Sinä päätät. 2018. [Online] Available at: <https://www.vttresearch.com/fi/uutiset-ja-tarinat/mita-smart-city-tarkoittaa-sina-paatat> [Accessed 25.3.2020]

Mustonen, V. et al. 2014. Älykäs kaupunki – Smart City, Katsaus fiksuihin palveluihin ja mahdollisuuksiin. Helsinki, Liikenne- ja viestintäministeriö [Online] Available at: <http://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/77892/Julkaisuja_12-2014.pdf?sequence=1&isAllowed=y> [Accessed: 3.4.2020]

Nordrum, A. 2017, Everything You Need to Know About 5G. [Online] Available at: <https://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g> [Accessed 25.3.2020]

Stevens, R. et al. 2012. Market Opportunity Analysis: Text and Cases, Pp 31-41. New York, Routledge. [E-Book] Available at: <https://ebookcentral.proquest.com/lib/metropo-lia-ebooks/reader.action?docID=668630> [Accessed 30.3.2020]

Vuorinen, T. 2013. Strategiakirja: 20 Työkalua. Helsinki, Talentum. [E-book] Available at: <https://www.ellibslibrary.com/reader/9789521420610> [Accessed: 3.4.2020]

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ROI and usage of smart city applications

Digital solution	Digital public transit payment system		Real-time public transit app		Open loop payment system		Mobility-as-a-service app		Predictive maintenance	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	4.0%	6.5%	3.6%	4.9%	3.5%	4.8%	2.8%	4.6%	1.6%	2.5%
Use	72%	76%	64%	88%	31%	60%	36%	52%	24%	32%

Table 28 Public transit ROI and use in cities

Digital solution	Curbside management		Public electric vehicle charging stations		Congestion charging		Real-time traffic management		Smart traffic signals		Smart parking apps	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	4.7%	5.8%	4.3%	5.0%	4.3%	5.3%	4.0%	6.1%	3.3%	4.7%	2.9%	4.0%
Use	36%	68%	76%	92%	39%	68%	77%	96%	51%	72%	54%	60%

Table 29 Traffic Management ROI and use in cities

Digital solution	Real-time water quality monitoring system		Real-time usage monitoring system		Water consumption tracking for users		Smart water meters		Predictive maintenance of water and sewer lines	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	3.9%	5.1%	3.9%	6.3%	3.2%	5.4%	2.9%	5.2%	1.8%	4.0%
Using	52%	96%	43%	68%	28%	52%	62%	72%	24%	36%

Table 30 Water management ROI and use in cities

Digital solution	Waste collection route optimization		Sensor enabled garbage bins		Digital waste tracking and payment		Recycling gamification		Real-time air quality monitoring	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	4.1%	6.0%	4.0%	5.4%	3.8%	6.8%	2.0%	2.8%	4.1%	7.0%
Use	47%	68%	23%	44%	37%	44%	29%	44%	40%	60%

Table 31 Waste collection and environment ROI and use in cities

Digital solution	Dynamic electricity pricing		Smart streetlights		Smart electricity meters		Smart electricity grid		Microgrids		Gamified energy reduction program		Energy consumption tracking for users	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	4.8%	5.7%	3.5%	4.7%	2.8%	4.9%	2.5%	4.5%	2.1%	2.1%	1.8%	2.5%	1.7%	2.2%
Use	47%	80%	59%	88%	64%	80%	35%	44%	25%	44%	17%	40%	31%	48%

Table 32 Energy and electricity ROI and use in cities

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Digital solution	Gun shot detectors		Real time crime mapping		Crowd sources crime reporting		Emergency notification apps	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	6.1%	7.3%	4.7%	7.3%	4.5%	5.5%	3.8%	5.9%
Use	9%	20%	34%	48%	28%	36%	57%	80%

Digital solution	Smart stations (kiosks)		Body cameras for police		Facial recognition software		Smart surveillance	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	4.0%	5.8%	2.3%	3.0%	1.9%	3.1%	1.9%	3.0%
Use	63%	80%	50%	60%	45%	68%	59%	72%

Table 33 Public Safety ROI and use in cities

Digital solution	First aid alerts		Infectious disease surveillance		Remote patient monitoring		Emergency route optimization		Data-based public health interventions		Real-time air-quality monitoring apps	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	5.6%	6.6%	4.4%	5.8%	4.3%	6.5%	3.5%	4.9%	3.5%	4.5%	3.1%	5.9%
Use	35%	56%	21%	40%	60%	88%	43%	56%	37%	68%	29%	68%

Table 34 Public Health ROI and use in cities

Digital solution	Digital tax filing		Digital licensing		Digital payments		Distributed government		Digitalized citizen services		"Just-in-time" civil services	
	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders	Total	Leaders
ROI	5.2%	7.1%	5.1%	6.6%	4.7%	6.0%	4.5%	4.6%	4.1%	5.2%	3.9%	6.2%
Use	63%	84%	44%	64%	85%	92%	37%	68%	63%	76%	44%	68%

**Table 35** eGovernance ROI and use in cities

Examples of Hyperconnected Cities Database
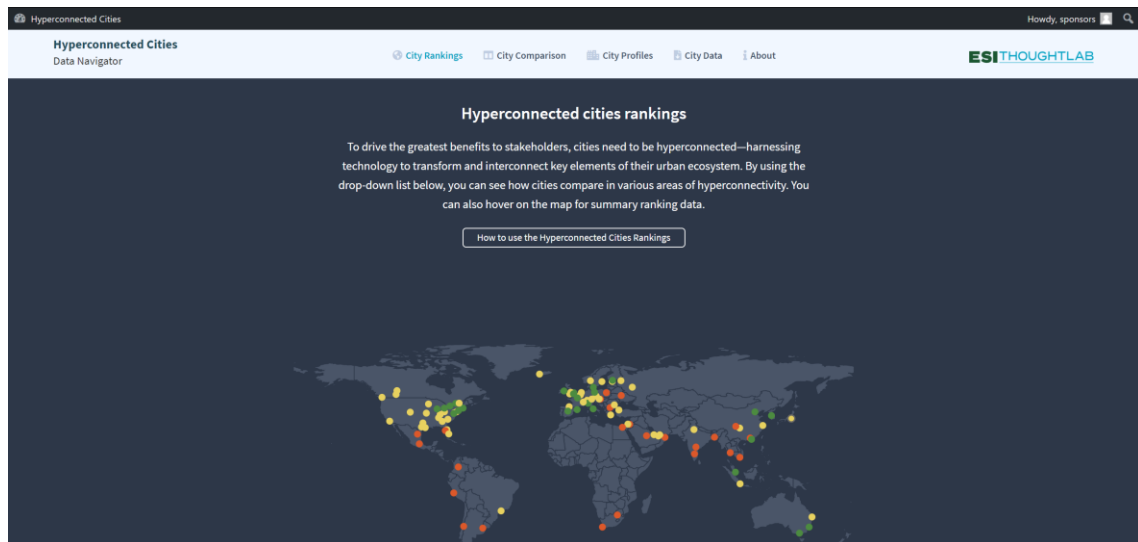
Picture 10 Hyperconnected cities rankings front page

Rank ▼	City	GDP per capita	City population	Population density (people/sqkm)
1	Singapore	$78,763	5.6 million	11,100
2	Hong Kong	$38,124	7.2 million	26,400
3	New York	$85,974	8.5 million	11,056
4	Seoul	$38,990	10.3 million	3,594
5	London	$64,560	8.7 million	1,851
6	Melbourne	$44,646	4.6 million	472

Picture 11 Hyperconnected cities ranking list

Metropolia
University of Applied Sciences
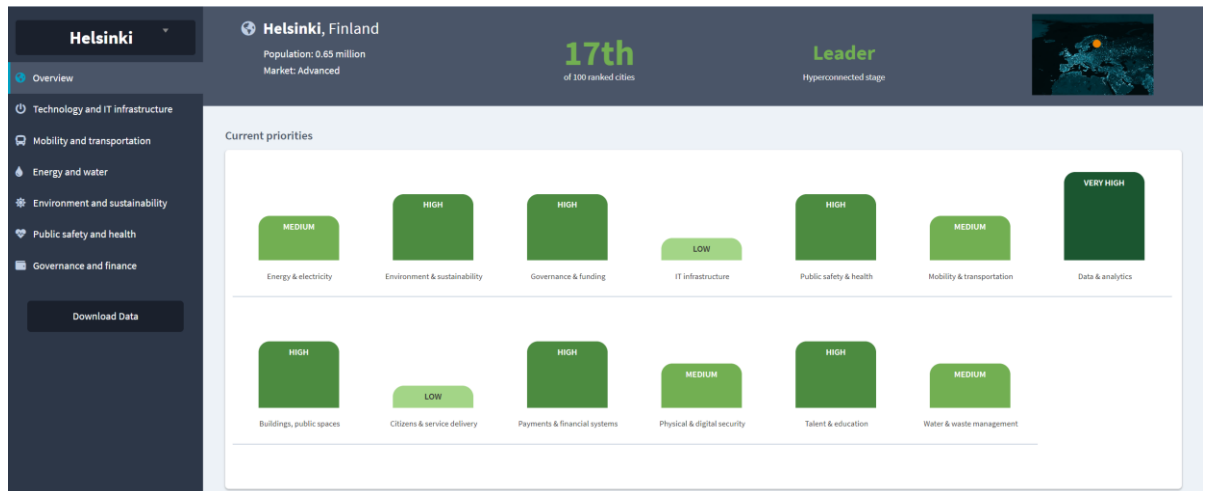
Picture 12 Hyperconnected cities Helsinki front page
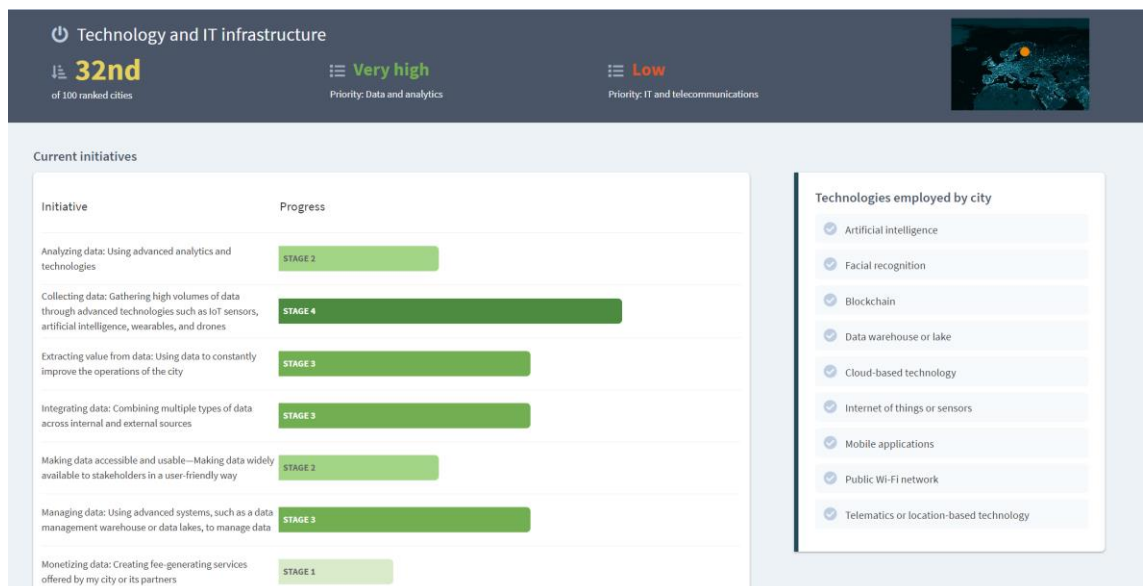
Picture 13 Technology and IT infrastructure in Helsinki
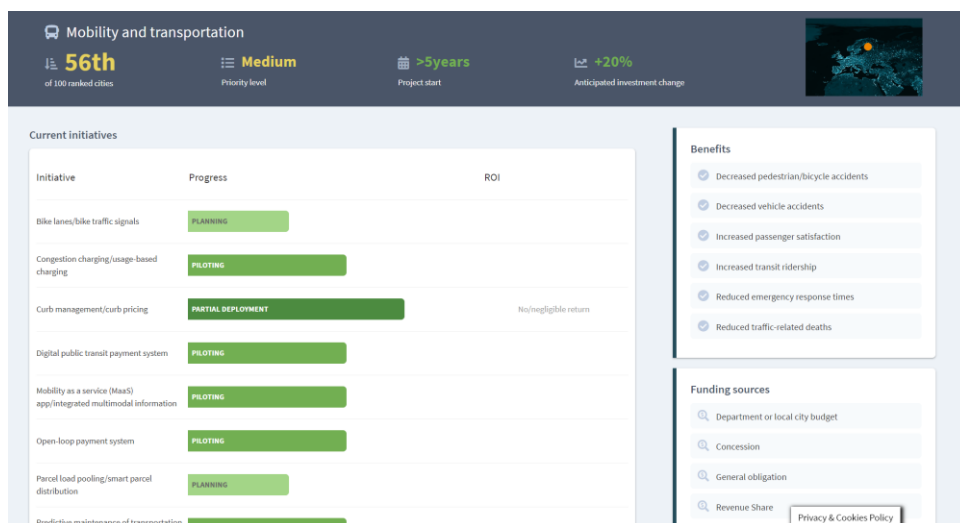
Picture 14 Mobility and Transportation in Helsinki