Implementing the Internet of Things Within Different Components of a Smart City: A Guideline

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ABSTRACT,
Due to rapid urbanization, the number of citizens is heavily increasing in cities all over the world. Because of this, new kinds of problems arise. To solve these problems, cities must be innovative. Therefore, a growing number of cities is transforming their way into becoming a Smart City. Smart Cities create innovative digital services, that are supported by the IoT. These IoT-services are then implemented within the different components of a Smart City, in order to solve problems within these components. The objective of this paper is to determine how three globally leading Smart Cities implement the IoT within different components of their city, in order to become a smarter city. This was done by conducting interviews with Nice, Palo Alto and Stockholm. Results of this paper will demonstrate that the IoT is a fitting tool for Smart Cities. However, for a Smart City vision to be realized, the IoT must be supplemented by other critical factors. Citizens, businesses and leadership prove to have a fundamental role in the Smart City development process, if not the most important role.

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1. INTRODUCTION

"Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how."

- ***Edward T. McMahon***

In the past, rural populations used to be dominant, but this has changed drastically. Over the last years, a shift appeared and nowadays, urban populations are considered more dominant. Today, the world's population consists of 7.6 billion people. According to the United Nations (2018), a percentage of 55% lives in urban areas. For the year 2050, this percentage is expected to increase to 68%. Because of this urbanization, the number of citizens is heavily increasing in cities all over the world. Therefore, new kinds of problems arise. Cities are forced to grow and find solutions for these problems. In order to find these solutions, cities need to be innovative. Because of this, a strategy that is widely used today, is to become a Smart City (Chourabi et al., 2012). According to Yin et al. (2015), a Smart City is a systematic assimilation of technological infrastructures which builds on progressive data processing, with the objectives of making city governance more efficient, a higher quality of life for civilians, businesses more flourishing and the environment more sustainable. Even though there is still not a city, that is globally seen as a real Smart City, some cities are leading the development process better than others. It can be said that attempts to become a real Smart City are made on a worldwide scale. According to IDC (2018), Smart City initiatives attracted technology investments of more than $81 billion globally in 2018. This number is expected to grow to $158 billion by the year of 2022. A concept that is often associated with the concept of a Smart City, is the Internet of Things (IoT). According to Giusto et al. (2010), the IoT is a communication paradigm which visualizes a near future, in which physical objects are equipped with microcontrollers, transceivers for digital communication and fitting protocol stacks that will make these objects able to communicate with each other and with the users. This future continues to develop, as 23,1 billion devices are connected in 2018. For the year 2020, this number is expected to increase to 30,7 billion devices and for the year 2025, it is expected that 75,4 billion devices will be connected worldwide (Medium, 2018). Although both concepts have been around for roughly two decades now, discussion about the exact definitions remains. However, the bigger picture of these concepts reveals strong similarities among past research. Smart Cities are indeed seen as the future to solve urbanization problems. For cities to become smarter, the shift from a traditional, to a more technological infrastructure is necessary. This results in the infrastructure for a Smart City, often being IoT-based. This IoT-based infrastructure allows cities to implement the IoT within different components of their city.

However, this is where a gap in literature exists. Many articles can be found about Smart Cities and it is often mentioned that the IoT is needed to become a Smart City, but every city is different. Every city's architecture is built in a unique way and therefore differently. Because of this, cities also cope with different problems. Traffic congestion can be a tremendous problem for one city, but completely irrelevant for another city. Although this other city might not have transportation and/ or mobility problems, environmental issues can have a huge influence within the challenges of this city. Since every city has its own unique problems and prioritizes its own city components, every city transforms into a Smart City in their own way. Research is missing on how cities implement the IoT within different components of their city, in order to become this Smart City. The

aim of this paper is, to dive further into this gap and gain a deeper understanding. Therefore, the research question of this paper is: *How do three globally leading Smart Cities implement the Internet of Things within different components of their city, in order to become a smarter city?*

The intent of this research is to answer this question. This will be carried out by interviewing three cities, that are globally seen as leading Smart Cities. As stated above, every city is different. By investigating how these cities successfully implement the IoT within their Smart City components, more insight will be gained on how these cities become a smarter city. In the Methodology section of this paper, this will be further explained. Although different research can be conducted about Smart Cities and the IoT, this study will focus on the implementation of the IoT within different Smart City components. Therefore, the aim of this paper is not to define exact definitions for these concepts or present a best practice. Results of this paper can serve more as a guideline for cities, all over the world, that want to become a Smart City and plan on implementing the IoT to do this.

The remainder of this paper is structured as follows. First, the Theoretical Framework will be introduced. Concepts, regarding the research question of this paper, will be more elaborated on. After that, the Methodology section will be discussed. Thirdly, the results of this research will be presented. After the results are given, a section will be presented in which the results are analyzed. Then, a discussion can be found. Finally, this paper ends by drawing conclusions and presenting recommendations.

2. THEORETICAL FRAMEWORK
In this section, the most important concepts regarding the research question of this paper will be explained. A framework will be set-up, by reviewing and evaluating existing literature.

2.1 Smart Cities
Over the last few decades, the concept of a Smart City began to raise enormous interest all over the world. Many writings can be found on Smart Cities within literature, yet there is not one shared definition for it. According to Batty et al. (2012), a Smart City is defined as a city where Information and Communication Technologies (ICT) are blended with traditional infrastructures, organized and unified by using advanced digital technologies. Technology appears to be a common thread in most definitions within literature, but not the only aspect of importance. According to Hollands (2008), a Smart City must be based on more than the use of ICT alone. This opinion seems to be supported by many different authors over the years, since most of the definitions found, are more integral than the one that Batty et al. (2012) gave. According to Nam and Pardo (2011), a Smart City consists of three core components. These three components are: technology factors, human factors and institutional factors. Their vision states that "smart" can be identified as innovative and revolutionary developments, leaded by new technologies. However, it is the social aspect, rather than smart technologies that stands fundamental within a Smart City. So, even though these authors state that smart developments are leaded by new technologies, they do not designate technology as the core component within a Smart City. According to Caragliu et al. (2011), a city is smart when continuous economic growth and a high quality of life, with thoughtful handling of natural resources through participatory management, is inflamed by investments in human capital, social capital, traditional (transportation) and current (ICT) communication infrastructure. While the meaning of the word "smart" is interpreted differently within this definition, the underlying core components of a Smart City are highly similar to the ones given in the previous definition. The following two highly-cited authors chose to state an even broader

definition of a Smart City. According to Neirotti et al. (2014), a Smart City should be capable of optimizing the practice and exploitation of tangible assets (e.g. transportation infrastructures, natural resources), as well as intangible assets (e.g. human capital, academic capital of firms). According to Zanella et al. (2014), the final objective of a Smart City is to make better use of the public resources, in order to raise the quality of the services which are presented to the citizens, while lowering the operational expenditures of the civic administrations. While this first definition presents a particularly general goal for Smart Cities, the second definition focuses on an extremely specific part of Smart Cities, namely the quality of services that are presented to its citizens. The objective that Zanella et al. (2014) gave, corresponds to Yin et al. (2015). They state that a Smart City is a systematic assimilation of technological infrastructures which builds on progressive data processing, with the objectives of making city governance more efficient, a higher quality of life for civilians, businesses more flourishing and the environment more sustainable. Although the opinions given above differ, these authors indicate great similarities within the bigger picture of their definitions. An opinion that remained shared over the years, is that the use of technology in order to realize a Smart City vision is necessary. However, next to the use of technology, it can be argued that other factors play a fundamental role within the development of a Smart City as well. According to Albino et al. (2015), every city should strive towards an integrated development of these different factors.

Now that the Smart City concept itself has been more elaborated on, the next aspect regarding Smart Cities and the research question of this paper will be further explained. A Smart City can be divided into several different fields, in which a city implements the IoT. Many articles about this topic can be found within literature. The most common terms found for these fields, are *Smart City components* ((Al Nuaimi et al. (2015), Nam & Pardo (2011), Lombardi et al. (2012), Silva et al. (2018) and Venkat Reddy et al. (2017)) and *Smart City (application) domains* ((Habibzadeh et al. (2018), Khan et al. (2013), Neirotti et al. (2014), Talari et al. (2017) and Yin et al. (2015)). Other terms, such as *Smart City characteristics* (Arroub et al., 2016) and *Smart City aspects* (Arasteh et al., 2016) can be found as well. Although the wording is different, the intentions of these authors are similar. This intention is to determine the different components of a Smart City, in which the IoT can be implemented. After review and evaluation of the components, mentioned by the authors stated above, this paper will define nine main components of a Smart City. These components are: Smart Environment, Smart Transportation and Mobility, Smart Governance, Smart Citizens, Smart Energy, Smart Buildings and Homes, Smart Healthcare, Smart Economy and Smart Security. In Figure 1, an illustration of this can be found. In the Appendix section of this paper, Table 1 and Table 2 can be found. The components in Figure 1 are composed out of buzzwords, mentioned by the 12 authors stated above. Table 1 presents an overview of this composition. Table 2 displays an overview of how many times each component is mentioned by the authors. The word "smart" in this context implies the optimization of more efficient and innovative developments, that are leaded by intelligent and state-of-the-art technologies, which in this way raise the quality of services provided in these components of a Smart City. Further elaboration on these Smart City components, will be discussed in the Methodology section of this paper.
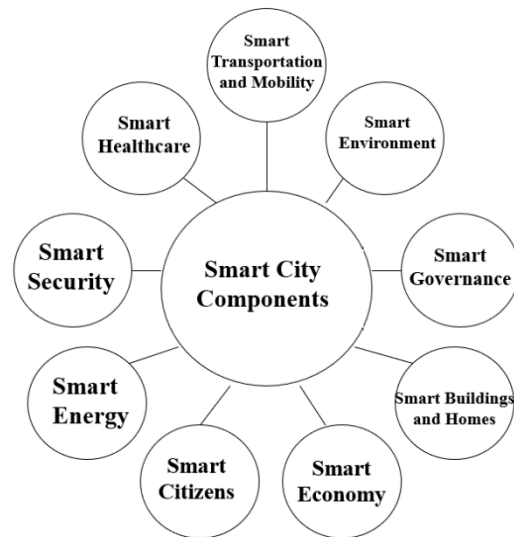

Figure 1. The components of a Smart City

2.2 The Internet of Things

Another concept that has raised worldwide interest over the years and is frequently mentioned when talking about Smart Cities, is the Internet of Things. Like the concept of a Smart City, the IoT is an extensive concept within literature and therefore, there are many different opinions, views and definitions on it. According to Giusto et al. (2010), the IoT is a communication paradigm which visualizes a near future, in which physical objects are equipped with microcontrollers, transceivers for digital communication and fitting protocol stacks that will make these objects able to communicate with each other and with the users. According to Zanella et al. (2014), the intention of the IoT is to make the Internet even more engaging and omnipresent, by allowing easy entrance and communication with a large variety of devices so that it can support the development of a number of applications which make use of the possibly gigantic bulk and diversity of data produced by objects to present new services to citizens, companies and public administrations. According to Miorandi et al. (2012), the IoT can be seen as the change form an Internet which is only used for connecting end-user devices, to an Internet which is used for connecting physical items, that interact with each other and/ or with humans in order to present a service that embraces the need to rethink about a new some of the traditional pathways commonly used in networking, computing and service management. As stated by Atzori et al. (2010) as well, the IoT should indeed be considered as part of the Internet of the future, which is expected to be dramatically different from the Internet we use today. According to them, the objective of the IoT is to enable communications with and among smart objects. Gubbi et al. (2013) state that the IoT can be seen as interconnection of sensing and actuating devices presenting the skill to share information across platforms through a unified framework, evolving in a shared operating image for enabling innovative applications. According to Al-Fuqaha et al. (2015), the IoT enables physical objects to see, hear, think and execute task by making them communicate with each other, without any human engagement, to share information and to coordinate decisions. Therefore, by profiting from its underlying technologies, the IoT transforms these objects from being traditional to smart. Looking at these different definitions, strong similarities appear. Therefore, this paper will provide its own definition. The IoT can be seen as an Internet that interconnects a large variety of physical objects, enabling these objects to communicate with each other, as well as with users, without any

human engagement. During this communication, gigantic amounts of data are exchanged, resulting in the creation of new and innovative services.

2.3 An IoT-based Infrastructure

It is now been more explained what the Smart City and IoT paradigms are about and in which components of a Smart City, the IoT can mainly be implemented. However, for the IoT to be implemented successfully within these components, a fitting underlying IoT-based infrastructure is necessary. This underlying IoT-based infrastructure enables cities to truly implement the IoT within desired Smart City components in their own city. This opinion is widely shared within literature. According to Hernández-Muñoz et al. (2011), an IoT-based infrastructure supports the complexity of different sensors set up in urban environments. It also enables to simplify the composition of interoperable services within a Smart City. In 2012, Balakrishna stated that, sensor-enabled smart objects demonstrate to be the essential feature for the interconnected infrastructures of the future. This infrastructure forms the basis of a Smart City. According to Sánchez et al. (2013), the use of an ICT-based infrastructure together with the traditional utilities and services infrastructures is seen as the next big step in the development of Smart Cities. According to Jin et al. (2014), the IoT can be seen as the key technological enabler for the infrastructure of a Smart City. Sicari et al. (2015) stated that, a flexible infrastructure is necessary within a Smart City, because of the large number of interconnected devices. Patti & Acquaviva (2016) stated that, the IoT is believed to be the key component to move towards a Smart City. According to Corici et al. (2016), an infrastructure where end device connectivity is monitored and IoT communication reliability assured, is key for a Smart City. According to Lynngaard & Skouby (2016), a progressive IoT infrastructure is a key feature to realize a Smart City. According to Joseph et al. (2017), an IoT-infrastructure should ensure that the sub-systems of a Smart City are intelligent enough to communicate and work interconnected with each other. Victoria Moreno et al. (2017) stated that, IoT-based infrastructure is being used worldwide for building future Smart Cities. According to Rathore (2017), an IoT-based infrastructure is necessary to fulfill the needs of a Smart City. According to Gope et al. (2018), in future Smart Cities, devices should be connected to IoT-based infrastructure. Bibri (2018) stated that, the IoT is one of the key components of the ICT infrastructure of sustainable Smart Cities as an emerging urban development approach due to its great potential to advance environmental sustainability. According to Cheng et al. (2018), to enable the IoT services, deployed within a Smart City, infrastructure should form a large scale IoT system with widely deployed IoT devices. Although trends often appear, regarding the IoT and Smart Cities, it can be read that this is an opinion that indeed remained shared over the last decade and especially in recent years. The importance of an IoT-based infrastructure for Smart Cities is clear. In order to implement the IoT within Smart City components, an IoT-based infrastructure is indispensable. Therefore, it can be seen as the backbone for building a Smart City.

2.4 The Implementation of the IoT

Above, the importance of an IoT-based infrastructure for Smart Cities can be read. Although the aim of this paper is not to design a best practice infrastructure, it is important to clarify how actual implementation of the IoT within Smart City components can be realized from an underlying IoT-based infrastructure. Based on the decomposition of the IoT-based infrastructure concept, the implementation process will therefore be further explained below.

Many writings about IoT-based infrastructures for Smart Cities can be found in literature. Often, the infrastructures model a Smart City in layers that starts with data generation ((Anthopoulos & Fitsilis (2010), Gaur et al. (2015), Jalali et al. (2015), Jin et al. (2014) and Wenge et al. (2014)). This data generation is used by an application and results into a service or processed data that serves an end-user. Next to that, many infrastructures model a data flow where sensors and devices collect data and a dispersed network is used for transmission ((Anthopoulos & Fitsilis (2010), Filipponi et al. (2010), Gaur et al. (2015), Jalali et al. (2015), Jin et al. (2014) and Wenge et al. (2014)). This data flow allows the formation of a layered and generic IoT-based infrastructure for Smart Cities. According to Berkel et al. (2018), the baseline infrastructure for Smart Cities consists of four layers. These layers are as follows:

Physical Layer. This layer models every sensing device that is available within a Smart City (e.g. RFID, mobile phones, weather sensors, etc.). Therefore, the central component within this layer are sensors.

Technology Layer. This layer consists of concepts needed to store data, handle data and host applications. The database within a Smart City, consists of four types of data: raw data (directly from the sensors), processed data, analyzed data and third-party data (for enhancement of analytics or smart services). Data and application servers can either be in the cloud or locally.

Application Layer. The Application Layer consists of two types of applications. These types are, applications that process data and data analysis applications. Applications that process data might also filter, clean and/ or transform data. These applications assure that the database is in possession of data, that can later be used by other applications. Data analysis applications use the processed data and transform it into useful information.

Business Layer. This layer consists of high-level processes. The implementation of the Smart City determines all processes that are necessary. Through these processes and data, generated by underlying applications, a smart service is delivered. The way it is delivered, depends on (among others) the function of the service.

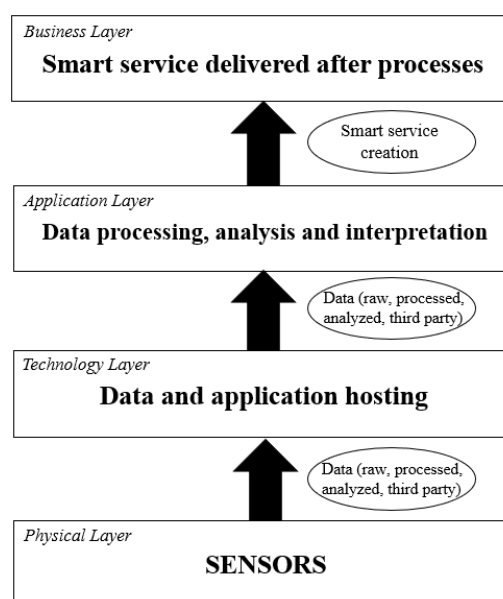Below, Figure 2 presents an illustration of these different layers.

Figure 2. Layers of an IoT-based Infrastructure

3. METHODOLOGY

3.1 Research Design

The exact way of how cities implement the IoT within different components of a Smart City, is such a complex topic, that in this study was chosen for a case study research strategy. According to Schramm (1971), The essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken. how they were implemented, and with what result. According to Yin (2003), case study as a research strategy comprises an all-encompassing method, with the logic of design incorporating specific approaches to data collection and to data analysis. In this sense, the case study is not either a data collection tactic or merely a design feature alone, but a comprehensive research strategy. In order to answer the research question of this paper, a total of three semi-structured in-depth interviews were conducted. The reason that the interviews were structured this way, is because this foster learning about individual experiences and perspectives on a given set of issues (DiCicco-Bloom, 2006). Every interview, an expert from a different Smart City around the world was questioned. These cities were chosen, based on a distinction. Nine Smart City components were determined within the Theoretical Framework section of this paper. Although all three cities have implemented the IoT, in order to become a smarter city, they do not primarily focus on the same Smart City component(s). This was done purposely, to gather more understanding and insights on how cities implement the IoT to achieve different objectives. Next to the implementation of the IoT, these cities share another similarity. This is, that they are globally seen as leading Smart Cities. As mentioned above, individual experiences and perspectives on a given set of issues were needed to solve the research question of this paper. Since the exact definition of a Smart City remains unclear to this day, the experiences of cities that are globally seen as leading Smart Cities, will be the most valuable in order to answer the research question. Therefore, interviews with experts from these specific cities were conducted. Below, it will be precisely explained, based on what every city was chosen specifically and why it was appointed as a leading Smart City.

3.2 Nice, France

According to United Smart Cities (2017), Nice is recognized as a world pioneer and well-known Smart City. In 2015, Nice opened the first "Smart City Innovation Centre" in France. The city focuses on the Smart Energy component, as it is home to Nice Grid, the first French Smart District demonstration project. Next to that, Nice wants to achieve economic development through a sustainable and environmentally-friendly vision. Therefore, the City of Nice focuses on the Smart Transportation and Mobility component and the Smart Environment component as well.

3.3 Palo Alto, United States

Being part of Silicon Valley, Palo Alto is pioneering the concept of a Smart City for many people (Van Belleghem, 2017). This city shapes its vision and mission around technology to become a digital leading city. Palo Alto wants to solve urban problems by using technology. The city makes use of an open data system, that consist of real-time data, to find solutions within different Smart City components. A mainly focused component for Palo Alto is Smart Transportation. Next to that, the city appears to be focusing on Smart Environment as well, stating they want to have an 80% carbon reduction as a goal for the year 2030.

3.4 Stockholm, Sweden

Stockholm is seen as one of the top Smart Cities in the world ((Komninos (2014), Ching & Ferreira (2015) and Angelidou (2017)). In the year 2010, the city of Stockholm was rewarded with the European Green Capital Award (European Commission, 2010). Next to that, Stockholm focuses on Smart Transportation and Smart Energy. In 2017, the city of Stockholm ranked 5th in The Top 10 Smartest Cities in the World (Luciano, 2017). According to CITO IO, Stockholm ranked 16th in The Top 50 Smartest Cities in the World 2018. This same year, Cision (2018) rewarded Stockholm with the 15th place worldwide. Because of these reasons, Stockholm was appointed as a globally leading Smart City and therefore chosen for this research.

3.5 Interview Design

The semi-structured interview consisted of a total of 33 questions. From these 33 questions, 9 of the questions were closed-ended and 24 were open-ended. The closed-ended questions were used to set up a subsequent open-ended question. Since the aim of this research was to get a deeper understanding of how cities implement the IoT within different components of their city, in order to become a smarter city, the study was exploratory of nature. Therefore, the focus was mainly on the open-ended questions. According to Kastl (1970), open-ended questions are a suitable tool in interviews to get an understanding of certain issues. By using open-ended questions, the interviewee is given the chance to give his view on the topic, without being constrained by scales and the pressure of giving relevant information. Although the primary focus was on the open-ended questions, all questions were constructed in-line with the research question of this paper and therefore helped to get closer to answering this question. There were also several questions that were constructed in-line with specific sections of the Theoretical Framework. This was done, in order to substantiate the questions better and therefore get better alignment. The interview started with an introduction about the main topics and why this research was conducted. After the introduction, the interview was divided into four parts. The first part aimed at gathering information about the interviewee's function and how this relates to the IoT and Smart Cities. The second part of the interview aimed to find out how the IoT-based infrastructure is built up and whether it consists of layers. After that, the third part asked questions about how the IoT is implemented in every city. The final part of the interview asked questions about the lessons that each city learned from their Smart City development process. This part was of high value for presenting a guideline. The complete interviews can be found in the appendix of this paper.

3.6 Data Analysis

After the three interviews were conducted and all data was gathered, this data was analyzed. First, the data was analyzed in order to get results. This was done by recording and making a transcript of every interview. After the transcripts were made, they were coded. The transcripts were analyzed and given answers, throughout the entire transcript, were linked to the corresponding interview questions. Also, open labels were attached to specific answers. So, open coding was performed. This was done, to present the right findings for the right interview questions. After the analysis for the Results section was done, the transcripts were coded again. This was done, in order to make statements in the Analysis and Discussion section of this paper. This time, axial coding was performed. A table that consisted of topics, based on the interview questions, was made. This table can be found in the appendix. Behind every topic, the results, as well as additional parts from the transcripts for this topic, were presented for every city. This way, a precise overview was obtained about the views of every city on each topic. These views were again analyzed and based on the opinions for every topic, statements were made.

4. RESULTS

The aim of this paper was to get a deeper understanding of how three globally leading Smart Cities implement the IoT within different components of their city, in order to become a smarter city. This aim was set, in order to present a guideline for other cities. In the Methodology section, it is described how this aim was strived for. Below, the key findings of every interview will be presented for each city. Although every interview consisted of 33 questions in total, this section will mainly present the findings for the questions that are critical for answering the research question of this paper. These findings will be presented in the first and second subsection. Next to that, the third subsection will present findings that are crucial for setting up a guideline. As mentioned, the complete interviews can be found in the Appendix as well.

4.1 The IoT-based Infrastructure

In this subsection, it is presented how important an IoT-based infrastructure is according to each city. Next to that, it is described how the IoT-based infrastructure is build up in each city. Also, it is presented whether it consists of specific layers. If possible, these layers are described as well.

4.1.1 Nice

"If we come back to how the Smart City of Nice was born, this is from political intentions to use digital innovation for developing the local economy of Nice." (A. Attour, personal communication, November 23, 2018). Therefore, Nice has built up their Smart City concept from an open-data perspective. According to Nice, their IoT-based infrastructure consists of specific layers. Further explanation about these layers was not given specifically. However, it was mentioned that public and private partnerships exist within the IoT-based infrastructure of Nice. The city of Nice is using the IoT to digitize existing services and to create new ones. "An IoT-based infrastructure is important for a Smart City, because it is a way to improve the performance of public services. Today we are living in a digital world. It is really important for cities to use an IoT-infrastructure to develop its services." (A. Attour, personal communication, November 23, 2018). On top of that, Nice agreed that an IoT-based infrastructure can be seen as the backbone for building a Smart City.

4.1.2 Palo Alto

"I had to begin the journey to explain, and I have been trying to do it now for a few years, that cities are beginning to be some of the largest utilizers of technology. It moved from being sort of an afterthought, about ten years ago, to now being the center of everything. I cannot think of a single project that the city of Palo Alto is doing today, where technology is not on the table." (J. Reichental, personal communication, November 21, 2018). According to Palo Alto, technology is going to be one of the largest components of how to enable positive change in the future. Over the last years, technologies have been more outward-facing in their opinion. So, these technologies touch community members, visitors and businesses. Palo Alto stated to have over 300 distinctive systems and therefore, a whole array of services and technologies, that run everything within the city. From their record management system, to software that helps with medical information in their ambulances. "In order to have the IoT, which seems to be one of the major trends in the Smart City space, you got to have a solid, fast, high-quality core backbone infrastructure." (J. Reichental, personal communication, November 21, 2018). Therefore, the IoT-based infrastructure of Palo Alto was stated to be built out of several critical elements. It consists of a strong core city-wide network, with as many fibers as possible. Data flows securely across this network. This includes everything from open-data, to analytics, visualizations and data-driven decision-making. This way, the data is opened-up and an ecosystem of participants exists. According to Palo Alto, a city cannot be smart without a data strategy. Next to that, it consists of sensors that are embedded in physical pieces within the city's architecture. This architecture was stated to be not necessarily formalized into specific layers.

4.1.3 Stockholm

According to Stockholm, an IoT-based infrastructure is extremely important for Smart Cities nowadays. "The reason though we are establishing this, is because we have a lot of challenges. We know that using the smart technologies can help us to be a better city, for the people that live there, work there and even the people that are visiting us." (C. Johannesson, personal communication, November 6, 2018). Overall, the opinion of Stockholm stated that smart technologies are a good thing for society. Their IoT-based infrastructure stated to contain most of the adequate technologies that are necessary for wireless communication. Although Stockholm did not want to disclose all their motives, they stated to have one of the most extended city-owned fiber networks in the world. Currently, they are reviewing further steps for their infrastructure portfolio. Stockholm confirmed that their IoT-based infrastructure consists of layers. However, it is still under construction and they did not want to disclose more information about it, during the time of the interview. Stockholm did agree on the question whether an IoT-based infrastructure can be seen as the backbone for building a Smart City. "There is no other part of our infrastructure that we can use to build a Smart City. So, in that case, probably yes." (C. Johannesson, personal communication, November 6, 2018).

4.2 The Implementation of the IoT

This subsection presents on which Smart City components each city mainly focuses and how the IoT is implemented within these components. So, key findings on how the implementation of the IoT enables each city to become a smarter city are presented.

4.2.1 Nice

According to Nice, their main-focused Smart City components are: mobility, energy and environment. Next to that, it was announced that the city plans on involving the healthcare component as well. "Nice aims to be a good Smart City in all these components. So, I would say that Nice wants to be an innovative Smart City in developing these components." (A. Attour, personal communication, November 23, 2018). An example of how they already used the IoT to become a smarter city, is a tramway, that makes use of IoT-services within their mobility component. By means of an IoT-based mobile application, users can organize their trip. Also, drivers of the tramway can anticipate on technical problems and resolve them, because of real-time data presented by IoT-services. An example for their energy and environment components, are sensors that collect data about the environment by measuring the air quality in Nice. "In order to help business companies to use this data for developing new innovative services, enabling consumers to transform their energy habits." (A. Attour, personal communication, November 23, 2018).

4.2.2 Palo Alto

Although Palo Alto stated to focus on many Smart City components, four main components were mentioned. The first component is transportation. "In many ways, probably that is the biggest Smart City area for the city of Palo Alto right now. It is everything from initiatives, to encourage people to not drive their car." (J. Reichental, personal communication, November 21, 2018). Examples of how Palo Alto is becoming smarter within this component, are that they try to make more people use public

transportation instead of their car. Next to that, they promote electric cars, bicycles and try to make different forms of non-car transport available. According to them, scooters and E-bikes are popular right now. Palo Alto also values the support of the emergences of autonomous vehicles. They act as a partner, by testing these vehicles and making sure that they are safe.

The second component was stated to be energy. "One of the things that makes Palo Alto unique in the United States, is that we are one of the few cities that provides all the utilities services. Electric, gas, water, waste-water. We even provide fiber internet! So, we have a lot of control over our utility's infrastructure." (J. Reichental, personal communication, November 21, 2018). Next to that, the city moved away from fossils and coals years ago and is therefore entirely carbon-free on the residential front. It was stated, that they are quickly moving there on the industry site as well. By having smart grid rolled-out, Palo Alto connects every house, to gain rich information for optimizing their energy distribution. This information is also used for operations and repairs.

A broad area of digital transformation was appointed as their third component. The city has deployed over 60 different digital experiences. "All our signatures are now done digitally. We do not have a lot of paperwork anymore, we digitize all our papers. We do not print as much as we used to. So, a big push on digital transformation and just better services! More efficient, more streamlined, more accurate and more managed services." (J. Reichental, personal communication, November 21, 2018).

The fourth component was stated to be sustainability in the environment. "In some ways, all the things I have already shared with you, are subscenes of that. Energy, transportation and digitization are all parts of the sustainability movement." (J. Reichental, personal communication, November 21, 2018). Next to that, it also means water-management technology by using sensors in the water. Also, it includes distribution of electric vehicle chargers all over the community. Other given examples were, gaining a better understanding of the city's greenhouse gas emissions and managing city buildings more energy-efficient.

4.2.3 Stockholm
Stockholm answered to mainly focus on the Smart City components: smart locks, smart traffic and smart lighting. Although it was not mentioned as one of the main components, Stockholm did confirm to receive the European Green Capital award in 2010. It was also stated that their environmental department is being active with smart technologies as well and that they are engaging in air pollution. "We need to be a fossil-free city within 2040" (C. Johannesson, personal communication, November 6, 2018). Stockholm performed small-scale tests within different areas of the city, to see if the technologies worked. These tests were converted into pilot projects within the components mentioned above. Several examples of how the IoT is used within Stockholm, in order to become a smarter city were given. "We have a lot of locks today that are electronic and used all over the world. In our case, that is not a smart lock, but just an electronic lock. A lock that you can open with an iPhone or a code for instance. When you connect that lock to a schedule for the people that are in the elderly care department and you can get the right person to open a certain door at a certain time, then you have a smart lock. So, that is why you can see the change from a schedule to who should have the ability to open that lock at the right time. That is when we talk about smart" (C. Johannesson, personal communication, November 6, 2018). For the smart traffic component, roads were equipped with sensors. This way, cars are registered, and traffic lights will anticipate on this by turning green earlier. Stockholm is also actively trying to use cameras in traffic, to obtain real-time data from cars, bicycles, pedestrians and public transportation. Within the smart lighting component, a pilot project was established. Next the use of LED-lighting in lampposts, the lampposts were equipped with sensors as well. These sensors are used among others for changing the light, measuring air pollution and measuring the wind temperature. Within the environmental department, sensors were put in lakes and the Baltic Sea to measure the water level.

Stockholm stated that data is the new thing. The IoT is one part of their new infrastructure, where they establish data. The data, generated from all the different projects described above, is then shared. The city counts on private companies to establish new services out of this data. "The city of Stockholm should establish the data that we can publish. That is our part. The next step is to make the smart services. I hope that should be done by private companies and not by the city of Stockholm. So, that is the next step in this. The first thing is that we establish the sensors and IoT. Then, by using the data from the sensors, we can establish new services." (C. Johannesson, personal communication, November 6, 2018).

"We have about 50 departments within the city of Stockholm. We need to work more horizontal." (C. Johannesson, personal communication, November 6, 2018). They now aim to cooperate more among these different departments. By working together, Stockholm wants to find smart solutions, based on real-time data that is gathered from their IoT-based infrastructure. These solutions should not only work for one department, but integrate into other departments as well. "That is one of the big challenges when you talk about digitalization." (C. Johannesson, personal communication, November 6, 2018).

4.3 Lessons Learned
In this subsection, important problems regarding the IoT-based infrastructure are presented. Also, it is presented whether these problems gave cities new insights. Next to that, critical requirements for an IoT-based infrastructure, according to each city and other important factors for building a Smart City, next to the IoT, are presented. Furthermore, it is presented how the IoT should be used within an ideal Smart City, according to each city. Lastly, recommendations are presented and whether each city thinks there is a best practice for becoming a Smart City.

4.3.1 Nice
"One strength of Nice is, that they build their Smart City concept on the open-data perspective." (A. Attour, personal communication, November 23, 2018). However, in practice, not all data was always accessible. This was stated to be a real problem for the development of IoT-services. Next to this problem, the privacy and acceptance of citizens regarding IoT-services were experienced as important problems. A more general problem was experienced to be the public administration services in Nice. "It is a really bad problem we have in France, the public administration. If IoT-services could improve the process of public administration services, it would be good." (A. Attour, personal communication, November 23, 2018).

According to Nice, the first requirement for an IoT-based infrastructure is technology-based. "You need it, to develop the infrastructure in order to implement the IoT." (A. Attour, personal communication, November 23, 2018). Next to that, the right digital capabilities need to be developed and enough storage space should be available. Other factors that are important for building a Smart City, next to the IoT, were stated to be: management and intention, funding and collaboration. "I think for developing innovations, build on IoT-technologies, we really need to improve the management of ecosystems of these

technologies and how we can implement them." (A. Attour, personal communication, November 23, 2018). Therefore, the right intentions and management of local public actors are needed to build a Smart City. Within all of the focused components of Nice, private and public partnerships services were included. Nice does not only collaborate with big companies, but also with local startups. Together with these companies, the city of Nice creates smart solution services. "I think we also have to give chance to startups." (A. Attour, personal communication, November 23, 2018).

Nice recommended other cities to assess citizen needs and to include citizens as co-actors within city projects, before developing these projects and corresponding technologies. Next to that, Nice recommended cities to care about citizen's privacy and their acceptance of the use and potential use of IoT-services. "When you use IoT-technologies, you collect a lot of personal and impersonal data and this data is sensitive." (A. Attour, personal communication, November 23, 2018).

"The building of a Smart City depends on the main characteristics of its own territories and its managers. I do not think there is a universal model to build a Smart City." (A. Attour, personal communication, November 23, 2018).

4.3.2 Palo Alto

"Everything is an obstacle. We face obstacles eight hours a day, every day." (J. Reichental, personal communication, November 21, 2018). Priority in city governance was named to be the first and probably most important one. Cities cannot do everything and therefore, difficult choices must be made. The second challenge was stated to be talent. In some cases, the right people are not available for the work that must be done, or people need to be trained. "Even through your best tempts to get grants and loans and all the other kinds of mechanisms, there is just not enough money to do everything you want to do. So, money would be number three." (J. Reichental, personal communication, November 21, 2018). Leadership was named as the fourth and last constraint. It was stated that huge issues will arise, if a leader is not on-board, or when there are misalignments of priorities. As can be read in the first subsection, Palo Alto stated several critical requirements for an IoT-based infrastructure. "Then, you have to have the mindset, the vision, the strategy and the governance. Those will be the additional layers on top of it." (J. Reichental, personal communication, November 21, 2018). Next to those factors, human capital was also mentioned as an important factor for supporting the build of a Smart City, next to the IoT.

Palo Alto gave three recommendations for other cities. The first one, was that it all begins with leadership. "I think cities should not be shy to use the term Smart City. The same time, they get the opportunity to define it any way they like." (J. Reichental, personal communication, November 21, 2018). City managers and city leaders need to be talking through the language of positive change through technology. The second one, was to look for partnerships. Especially for the smaller cities. According to Palo Alto, there are many creative ways of public and private partnerships to enable this. The third one, was to develop a multi-year strategy that everybody agrees on. "The worst strategy in the world is: when you do right, you never change. A good strategy is: when you do right, you evolve as circumstances change. So, I will courage cities to have an agreed and articulated technology strategy to support their important goals as a community." (J. Reichental, personal communication, November 21, 2018).

According to Palo Alto, every city must decide whether becoming a Smart City is a mission they want to take on. Once that decision is made, the rest is operational. "The best practice is to make sure that there is a strong supportable vision for it and then execute on it." (J. Reichental, personal communication, November 21, 2018).

4.3.3 Stockholm

According to Stockholm, the first obstacle is a new business model. Find out who is going to pay for it. A more important obstacle was stated to be citizen's security. "People are of course a little bit afraid when we use IoT-solutions. What will happen? Will they be registered? What do we do with personal information? We have to be aware of the secureness. We have to take care of those issues, before we make this big." (C. Johannesson, personal communication, November 6, 2018). The development of an IoT-based infrastructure was seen as a continuous process. "We are supposed to solve the problems. We are aware of them and know we have to deal with them. Some of the problems, we know that we will take care of beforehand. We know that we will probably find some problems when we are there, and we have some of the solutions. So, we have to solve these problems at that time." (C. Johannesson, personal communication, November 6, 2018).

Stockholm stated that adaptability to a city's needs is the most important requirement for an IoT-based infrastructure. Next to that, technologies that are used, must meet security requirements as described above.

Apart from the IoT, citizens have a fundamental role within the Smart City development of Stockholm. It was stated that everything the city does, is for them. "When we work with the strategy, we asked a lot of citizens. To see what opinions, they had. So, they were included. Not only citizens, we also asked academia and the businesses. We will continue to do that." (C. Johannesson, personal communication, November 6, 2018). Therefore, Stockholm views the Smart City development process as a democratic issue as well.

The recommendation Stockholm gave for cities, that want to use the IoT to become a Smart City, was to cooperate. "When you establish an infrastructure with IoT, you have to cooperate with the cities among you." (C. Johannesson, personal communication, November 6, 2018). Stockholm encouraged cities to see what other cities do, learn from international studies, try to look behind this and talk with people from different cities.

Stockholm did not think that there is a best practice for becoming a Smart City, since this was stated to depend on the city itself.

5. ANALYSIS OF THE RESULTS

The purpose of this section is to compare the results section with the theory section. Striking similarities and differences, regarding the most important aspects of the research question, will be highlighted. These aspects are: the main focused Smart City components of each city and the implementation of the IoT.

5.1 Smart City Components

Within the theory section of this paper, nine Smart City components were determined. These components were: Smart Environment, Smart Transportation and Mobility, Smart Citizens, Smart Governance, Smart Energy, Smart Buildings and Homes, Smart Healthcare, Smart Economy and Smart Security. All three cities stated to focus on the Smart Environment component, as well as the Smart Transportation and Mobility component. These components were also mentioned the most by the authors in Section 2.1 of the Theoretical Framework. Nice and Palo Alto stated to focus on the Smart Energy component, while the city of Stockholm talked about Smart Lighting.

Operations within the Smart Energy and Smart Lighting components illustrated strong similarities. The Smart Healthcare component was mentioned once, by the city of Nice. The city is not focusing on the Smart Healthcare component right now, but they are planning to do so in the future.

Components that were determined in the Section 2.1, but were not mentioned by any of the cities as main focused components are: Smart Governance, Smart Citizens, Smart Building and Homes, Smart Security and Smart Economy. Remarkable is that although Smart Governance and Smart Citizens were mentioned many times in Section 2.1, they were not stated as main focused components by any of the cities. However, both components did turn out to play a fundamental role within the Smart City development of each city. Surprisingly with a look at section 2.1 as well, the Smart Security component also displayed to play a large role, as all cities agreed that the secureness of IoT-services is of high importance. Further elaboration on this will be given in the Discussion section of this paper. Smart Buildings and Homes were more seen as part of the Smart Energy component, as all cities gave examples of how they wanted to extend their Smart Energy operations to buildings and homes located within their city.

5.2 The Implementation of the IoT

In the theory section, it was described that for the IoT to be implemented successfully within Smart City components, a fitting underlying IoT-based infrastructure is necessary. Therefore, the IoT-based infrastructure was stated to be the backbone for building a Smart City. This opinion was shared among all three cities, as none of the cities denied this statement. In contrast, it was in fact strongly agreed on. It was also described that this IoT-based infrastructure needs to be layered. Nice and Stockholm confirmed that their infrastructure was layered, while Palo Alto stated it not to be necessarily formalized into layers. Although Nice and Stockholm did not disclose what their layers look like, confirmation of the layers described in the theory section can be given largely. The overall answers of all three cities, stated the use of sensors to obtain data (Physical Layer). Next to that, it was stated that enough storage space is needed for this data and that the data needs to be handled (Technology Layer). In order to create new services, the data must be transformed (Application Layer). Finally, all cities spoke about the actual creation of new services, which confirms the Business Layer.

6. DISCUSSION

In the introduction, the research problem of this paper was stated. Research is missing on how cities implement the IoT within different components of their city, in order to become a smarter city. The aim of this paper therefore was, to dive further into this gap and gain a deeper understanding. The question that had to be answered to achieve this was: *"How do three globally leading Smart Cities implement the Internet of Things within different components of their city, in order to become a smarter city?"*

It turns out, there is not a best practice for doing this. However, a much deeper understanding is indeed gained. Findings of this paper display that the IoT can be seen as an enabling tool, for cities to become smarter. Within different components of a Smart City, the IoT can be implemented, in order to connect physical objects and generate large amounts of (real-time) data. As Al-Fuqaha et al. (2015), Gubbi et al. (2013) and Zanella et al. (2014) stated, this data then needs to be shared and made openly accessible, in order to digitize existing services within these components, as well as to create new services. The role of the IoT-based infrastructure in this, is to support the implementation of the IoT. Without an underlying and fitting infrastructure, a city's desired Smart City vision cannot be realized. Therefore, it can indeed be seen as the backbone for building a Smart City. These findings are strongly in-line with the statements made in Section 2.3. In particular with the opinions of Cheng et al. (2018), Jin et al. (2014) and Patti & Acquaviva (2016). A remarkable finding, however, is that despite many substantiations for a layered infrastructure in Section 2.4, this does not turn out to be a prerequisite for a strong and supportive infrastructure, as not all cities within this paper chose to formalize it this specifically. While it does not necessarily have to be layered, in order to be supportive, it must consist of several critical elements. First of all, sensing devices are needed to gather data. Then, a strong core city-wide network is needed for this data to flow through the infrastructure openly and secured. Next to that, enough storage space must be available. Lastly, applications that can process, filter, clean, transform and/ or analyze the data are needed. This way, data can be transformed into actual services.

Even though this explains how the IoT can be implemented within different Smart City components and the role of an IoT-based infrastructure in this process, this paper emphasizes that a Smart City cannot be realized by using the IoT alone, as was stated by Hollands (2008). Findings strongly support the opinion of Nam & Pardo (2011). Their vision stated that "smart" can be identified as innovative and revolutionary developments, leaded by new technologies. However, it is the social aspect, rather than smart technologies that stands fundamental within a Smart City. As mentioned in Section 5.1, citizens and governance play a fundamental role within the Smart City development of each city. The needs, privacy, security and acceptance of citizens are seen as major challenges for every Smart City. This is because, all the Smart City objectives that are set by cities, are eventually aimed at the people that live and work there. As stated by Caragliu et al. (2011), Yin et al. (2015) and Zanella et al. (2014), a Smart City aims to improve the quality of the services presented to its citizens and the overall quality of life. Therefore, a strategy should be developed that includes citizens and that is adaptable to their needs and those of the city. Next to including citizens, it turns out that collaborations with businesses are of high importance as well. Findings demonstrate that cities count on businesses, to create new and innovative services, out of the data that a city presents to these businesses. This does not only apply to large companies, but to local startups as well. Even if citizens, businesses and preferably academia are included and integration of the technological aspect, as well as the social aspect of a Smart City has occurred, the role of governance becomes visible. During the Smart City development process, leadership must ensure that the needs of citizens are continuously strived for and collaborations are established. This should be done by setting the right priorities, maintaining the right intentions and aligning all parties involved. Only this way, positive change through the IoT can be achieved.

6.1 Conclusion

To conclude, the quote at the beginning of this paper will be explained. This quote stated: *"Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how."* It is a fact that more and more cities around the world are coping with new and increasing problems, due to rapid urbanization. Therefore, these cities are trying to find new digital solutions for these problems. As stated by Atzori et al. (2010), the IoT is indeed part of the Internet of the future. Innovative IoT-services, implemented within different components of a city and supported by an underlying IoT-based infrastructure, indicate to be an enabling tool that fits Smart Cities. Eventually, the majority of cities worldwide will have to

move more towards a Smart City vision. Therefore, it is not a question whether your city will change or whether the IoT will be used to do this. The question is indeed how. This paper presented how three globally leading Smart Cities implement the IoT, in order to become a smarter city. However, results also demonstrated that the use of the IoT must be supplemented by other critical factors. Businesses are needed to realize the creation of innovative services out of gathered data and the needs of citizens play a fundamental role in developing a fitting strategy. Once this strategy is developed and agreed on, leadership should keep a city's Smart City development process on the right track. This paper presented a guideline for doing this, but certainty cannot be given for every city. In the end, every city has its own challenges and should therefore develop its own strategy to achieve the desired growth, without destroying community character. After all, a Smart City is created for the sake of its citizens.

6.2 Recommendations

The main recommendation for other cities, is to include citizens within the development of a Smart City strategy. Before starting the actual development process, a city should assess the needs of its citizens and include them as co-actors. Citizens should not only be included at the start, but continuously through the whole realization of the Smart City vision. This way, more alignment occurs throughout the entire process and practical benefits are also experienced because of this. Over the long-term, a great deal of time and therefore money will be saved.

The second recommendation is to collaborate. This recommendation is especially useful for smaller cities or cities that just started their Smart City development process. Collaboration with businesses turns out to be necessary, in order to create innovative services out of data. Next to large companies, startups should be given a chance as well, as these companies might offer unique and out-of-the-box solutions. Apart from businesses, other cities are also a valuable option to collaborate with. Plenty can be learned from the experiences of these cities.

Lastly, a more practical and specific recommendation. This is to prioritize the digitalization of a city's public administration services. By doing this, the overall life quality of citizens is improved, as it affects them directly. Next to that, large amounts of real-time data are created. Since data, that is gathered from public administration services, is often needed within different Smart City components, it also fosters sharing of data across these components and making it openly-accessible.

6.3 Future Research

The most important direction for future research, that derived from this study, is the acceptance of citizens towards IoT-services within a Smart City. Not only will this help to develop a Smart City strategy that is more adaptable to the needs of citizens, it will also be fundamental for the next step in Smart City development. Today, privacy concerns are obstructing the full potential of how the IoT can be implemented within a Smart City. Therefore, it is important to investigate at what point an intervention, based on ethnic motives, must be made. Research on this subject will give more insight on how the Smart City development now, as well as in the future, will be affected.

6.4 Limitations

Even though every effort has been made to carry out this research without bias, there are some limitations within this paper that should be mentioned.

6.4.1 Sample Size
During this research, semi-structured qualitative interviews were conducted. This specific design of interviews is highly time-consuming. Since this research had to be conducted within a limited period of time, interviews were conducted with a relatively small number of cities. There are many cities that are trying to become a Smart City worldwide. Therefore, it cannot be demonstrated with certainty that the results of this study are also applicable on other Smart Cities. It could be that there are Smart Cities, that focus on the exact same components as the Smart Cities within this research do, but wield a completely different approach. Further research must elaborate more on this.

6.4.2 Subjectivity
Although there are many advantages in applying a qualitative research method, there is also a considerable disadvantage. Unlike the results of a quantitative research, the results of a qualitative research, lack statistical representation. Therefore, the results cannot be verified and/ or duplicated and are therefore difficult to accept as factual. Investigated concepts can be of high importance for one person, but completely irrelevant to a different person. Because of this, ambiguities about the gathered data may arise. Although it has been tried to maintain an objective vision throughout the entire research, it might be that a subjective interpretation of the collected data unknowingly influenced the outcomes of this research.

6.4.3 Skype
The interviews during this research, were conducted through Skype. Although Skype enables us to conduct interviews with cities all over the world and some of the interviews made use of a camera, it still removes a dimension compared to face-to-face interviews. There is a different atmosphere when the interviewee is actually in the room. Next to that, nonverbal communication has a large impact and therefore, plays an important role in the interpretation of answers. Therefore, the overall experience is different when using Skype. This might have had influence on the outcomes of this paper.

6.4.4 Industry-related Expertise
Smart Cities and the IoT are complex fields of expertise. Even though interest and objectivity has been demonstrated regarding these concepts, there is a lack of specific skills, knowledge, experiences and expertise compared to experts within these fields. Therefore, the quality and interpretation of the gathered data, might be criticized by experts within the fields of Smart Cities and/ or the IoT.

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8. APPENDIX

Table 1. Construction of the Smart City components

Smart City component	Composed of the buzzwords
Smart Environment	*"Smart Environment" - "Natural resources and Energy" – "Environment"*
Smart Transportation and Mobility	*"Smart Transportation" – "Smart Mobility" – "Transport and Mobility" – "Transportation and Vehicle Traffic"*
Smart Governance	*"Smart Governance" – "Smart Governance and Smart Education" – "Other Policy Domains" – "Government"*
Smart Citizens	*"Smart Education" – Smart Citizens" – Smart People" – "Smart Human Capital" – "Economy and People" – "Smart Community"*
Smart Energy	*"Smart Energy" – "Smart Lighting" – "Smart Grid" – "Natural Resources and Energy"*
Smart Buildings and Homes	*"Smart Building(s)" – "Buildings" – "Smart Homes" – "Smart Living"*
Smart Healthcare	*"Smart Healthcare" – "Smart Health" – "Healthcare"*
Smart Economy	*"Smart Economy" – "Economy and People" – "Business"*
Smart Security	*"Smart Security" – "Smart Safety" – "Surveillance Systems"*

Table 2. Number of mentions per Smart City component

Smart City component	Mentioned by	Total number of mentions
Smart Environment	Al Nuaimi et al. (2015), Arroub et al. (2016), Habibzadeh et al. (2018), Khan et al. (2013), Lombardi et al. (2012), Nam & Pardo (2011), Neirotti et al. (2014), Talari et al. (2017), Venkat Reddy et al. (2017), Yin et al. (2015)	10
Smart Transportation and Mobility	Al Nuaimi et al. (2015), Arasteh et al. (2016), Arroub et al. (2016), Habibzadeh et al. (2018), Khan et al. (2013), Nam & Pardo (2011), Neirotti et al. (2014), Silva et al. (2018), Talari et al. (2017), Venkat Reddy et al. (2017)	10
Smart Governance	Al Nuaimi et al. (2015), Arasteh et al. (2016), Arroub et al. (2016), Khan et al. (2013), Lombardi et al. (2012), Nam & Pardo (2011), Neirotti et al. (2014), Yin et al. (2015)	8
Smart Citizens	Al Nuaimi et al. (2015), Arasteh et al. (2016), Khan et al. (2013), Lombardi et al. (2012), Nam & Pardo (2011), Neirotti et al. (2014), Silva et al. (2018), Yin et al. (2015)	8
Smart Energy	Al Nuaimi et al. (2015), Arasteh et al. (2016), Habibzadeh et al. (2018), Nam & Pardo (2011), Neirotti et al. (2014), Silva et al. (2018), Venkat Reddy et al. (2017)	7

Smart Buildings and Homes	Arasteh et al. (2016), Arroub et al. (2016), Lombardi et al. (2012), Neirotti et al. (2014), Talari et al. (2017), Venkat Reddy et al. (2017)	6
Smart Healthcare	Al Nuaimi et al. (2015), Arasteh et al. (2016), Habibzadeh et al. (2018), Nam & Pardo (2011), Silva et al. (2018), Talari et al. (2017)	6
Smart Economy	Arroub et al. (2016), Khan et al. (2013), Lombardi et al. (2012), Neirotti et al. (2014), Yin et al. (2015)	5
Smart Security	Al Nuaimi et al. (2015), Arasteh et al. (2016), Nam & Pardo (2011), Talari et al. (2017)	4

Appendix 1. The interview questions

Part 0 – Introduction of the Interviewee

1. Could you explain what your function is and how this relates to the IoT and Smart Cities?

Part 1 – The IoT-based Infrastructure

2. How is the IoT-based infrastructure of … built up?

3. Would you say that the IoT-based infrastructure of … consists of specific layers? (TF 2.4)

4. If yes, what types of layers? (TF 2.4)

5. How important would you say an IoT-based infrastructure is for a Smart City?

6. Would you say the IoT-based infrastructure can be seen as the backbone for building a Smart City? (TF 2.3)

7. Why? / Why not?

Part 2 – The Implementation of the IoT

8. A Smart City can be divided into a number of different components (e.g. Smart Mobility, Smart Environment, Smart Healthcare, Smart Citizens and Living, etc.). On which component(s) would you say … focusses the most? (TF 2.1)

9. How does … use the IoT to become a smarter city within these components?

10. What would be a specific example of this?

11. What is the ultimate objective for … as a Smart City within these components?

12. Could you explain how the IoT will be used to achieve this objective?

13. Apart from the different components of a Smart City, how did the IoT enable … to become a Smart City in general?

14. How does the IoT-based infrastructure fit into …'s bigger Smart City plan?

Part 3 – Lessons Learned

15. Were there at any point of the Smart City development of … problems/ obstacles regarding the underlying IoT-based infrastructure?

16. If yes, how were these problems solved?

17. If yes, did these problems give new insights about the requirements for …'s IoT-based infrastructure?

18. If yes, what were these insights?

19. If yes, how was the IoT-based infrastructure changed, in order for … to still meet its Smart City objectives?

20. What requirements does an IoT-based infrastructure always have to meet, for cities that want to transform into a Smart City?

21. Would you say that there are any other important factors, next to an IoT-based infrastructure, that are of high importance for building a Smart City?

22. If yes, what are these factors?

23. How would you say the IoT should be used within an ideal Smart City? (So, what role should the IoT have?)

24. Do you have any general recommendations for cities that want to use the IoT to become a Smart City?

25. If yes, what would these be?

26. Do you think every city can transform into a Smart City in the same way?

27. Why? / Why not?

28. Would you say that there is a best practice for becoming a Smart City?

29. Why? / Why not?

30. Which public and/ or private partners helped … to become a smarter city?

31. Companies like IBM, Cisco, Siemens, etc. are big players within the IoT-market. Which companies in the IoT-market are performing very well and offer real solutions for Smart Cities in your opinion?

32. Are there currently any specific trends for building a Smart City?

33. If yes, what are these trends?

Appendix 2. Coded Nice transcript

Interviewer: So, then let us move on to the questions. Could you explain what your function is and how this relates to the IoT and Smart Cities? (1)

Interviewee: Okay, I am actually an associate professor at the University Côte D'Azur. I am a member of the research institute named GREDEG. It is a research institute in economy, management and loan. So, as I am a researcher, I work about digital innovation, business models and knowledge management. More precisely, I study how knowledge management in digital innovation contributes to the business model innovation. Business ecosystem innovation in the specific case of Smart Cities. (1)

Interviewer: Thank you. So, you also have knowledge about the IoT-based infrastructure of Nice right?

Interviewee: Yes.

Interviewer: Okay. So, therefore the first technical question will be: How is the IoT-based infrastructure of Nice built up? Would you say it consists of specific layers? (2 + 3)

Interviewee: Could you repeat please?

Interviewer: Yes, of course! So, how is the IoT-based infrastructure of Nice built up? Would you say it consists of specific layers? (2 + 3)

Interviewee: Yes, it consists of layers. Like public and private partnerships. (2 + 3)

Interviewer: Those layers, could you give examples of it? (4)

Interviewee: I do not know how to say it in English. I am not sure about the examples, I am sorry. (4)

Interviewer: Okay. Is it okay if I mail that question afterwards?

Interviewee: Yes.

Interviewer: Okay, then I will mail this question afterwards. Then a bit more of a general question. How important would you say an IoT-based infrastructure is for a Smart City? (5)

Interviewee: So, it is important for Smart City because it is a way to improve the performance of public services. Today we are living in a digital world. It is really important for cities to use IoT-infrastructure to develop its services. (5)

Interviewer: Okay, thank you. Would you say the IoT-based infrastructure can be seen as the backbone for building a Smart City? (6)

Interviewee: Yes, it is. (6)

Interviewer: Okay, thank you. Then, A Smart City can be divided into several different components (e.g. Smart Mobility, Smart Environment, Smart Healthcare, Smart Citizens and Living, etc.). On which component(s) would you say Nice focusses the most? (8)

Interviewee: So, Nice focuses the most on the components: mobility, energy and environment. (8)

Interviewer: Okay! So, those are the three mainly focused components for Nice? (8)

Interviewee: Yes. Those are the three and a few months ago, they announced that they are going to add a fourth one, which is health. (8)

Interviewer: Okay, interesting! Thank you. For the components that are already focused, so the mobility, energy and environment. How does Nice use the IoT to become a smarter city within these components? (9)

Interviewee: For example, in the component mobility, they use IoT-infrastructure to digitize some existing services and also developing new ones. For example, 2 years ago, Nice did not have a tramway in the city. This is going to be developed, as we have the first one a year. It is a good one. It started working last September. This one is including IoT-services. For example, in line number 2 of the tramway, there are services on which mobile applications are built on IoT-services that help tramway users to organize their trip for example. They include also services built on IoT-technology to help tramway drivers to anticipate on technical problems and to help to resolve technical problems in real-time. (9)

Interviewer: Okay, interesting! Online, I indeed saw that you had the tram. Could you maybe give examples for energy and environment components as well? (9)

Interviewee: Energy, the main one is the technologies they use to measure the air quality in Nice. They implemented a lot of sensors, to collect a lot of data about the environment. To help business companies to use this data for developing new innovative services enabling consumers to transform their energy habits. (9)

Interviewer: Okay, thank you! So, energy and environment go a bit hand in hand then? (9)

Interviewee: Yes. (9)

Interviewer: Okay, thank you. Then, apart from the focused components right now, what would you say is the ultimate objective for Nice as a Smart City? (11)

Interviewee: It is quite a difficult question, because Nice aims to be a good Smart City in all these components. So, I would say that Nice wants to be an innovative Smart City in developing these components. These components are the front office of Nice as a Smart City. Its competence is, in helping and contributing to business model innovation in the field of Smart Cities. I say that because, if we come back to how the Smart City of Nice was born, this is from political intentions to use digital innovation for developing the local economy of Nice. (11)

Interviewer: Okay, thank you! Now a bit more of a general question. Would you say that there are any other important factors, next to an IoT-based infrastructure, that are of high importance for building a Smart City? (21)

Interviewee: If I understand your question, you would like me to give some examples of what are the next important IoT technologies?

Interviewer: No, actually what is important next to an IoT-based infrastructure. So, not only the IoT, but also other factors that are important for building a Smart City as well.

Interviewee: Okay. The factors that are important for building a Smart City?

Interviewer: Yeah, for building a Smart City. So, human capital is often mentioned and governance.

Interviewee: Okay. I think the main factor is of course funding. Enough funding for doing that. The more important one is management and intention. The intentions of public local actors. The third one, I think, is to manage to innovate in new ways for collaboration between public actors and businesses. I think for developing innovations, build on IoT-technologies, we really need to improve the management of ecosystems of these technologies and how we can implement them. (21)

Interviewer: Okay, that is a very clear answer, thank you! Then, back to the IoT-part of a Smart City. What requirements does an IoT-based infrastructure always have to meet, for cities that want to transform into a Smart City? (20)

Interviewee: The first one is the technical. You need it, to develop the infrastructure in order to implement the IoT. The second requirement, you have to develop digital capabilities. Digital capabilities are nowadays not all identified. Maybe if I can say another, it is to have a best storage space for collecting data. (20)

Interviewer: Okay, thank you. Do you have any general recommendations for cities that want to use the IoT to become a Smart City? (24)

Interviewee: I recommend them to before developing these technologies and their projects, to anticipate or to… How to say that? To assess citizens needs and citizens acceptance of these technologies and their potential use of these technologies. I also think it is really necessary for cities to care about how to protect citizens privacy. So, how they may manage to include in their projects, local citizens privacy concerns. As you know, when you use IoT-technologies, you collect a lot of personal and impersonal data and this data is sensitive. So, how they manage to include problems and question related to individual privacy concerns. So, I think the first point is before defining and beginning their project, is to care and pay attention to how to include citizens as co-actor of the project. (24 + 15)

Interviewer: So, really include the citizens. That is a very clear answer, thank you! This is really about the privacy of citizens and that it is a big problem nowadays for Smart Cities. Would you say there are any other big problems that Nice is facing when building a Smart City with regard to the IoT? (15)

Interviewee: A big problem is about the collection of data and open-data in generally, because… I should not say it, I think, but I think last year we said in Nice that we are open with data, so that companies could use it. But, concretely, when you begin a project in collaboration with companies, we notice that this data is not all accessible. I think this is a real problem. One strength of Nice is, that they build their Smart City concepts on the open-data perspective. (15 + 13)

Interviewer: Okay, thank you. Then, a more general question again. How would you say the IoT should be used within an ideal Smart City? (So, what role should the IoT have?) (23)

Interviewee: I would use IoT-services for simplifying public administrations services in Nice. It is a really bad problem we have in France, the public administration. If IoT-services could improve the process of public administration services, it would be good. (23)

Interviewer: Thank you! Another general question: Would you say that there is a best practice for becoming a Smart City? (28)

Interviewee: Could you repeat please, sorry?

Interviewer: Yeah, of course. Would you say that there is a best practice for becoming a Smart City? So, actually a best way.

Interviewee: No! I think there is not a best way for becoming a Smart City, because I think all cities and all territories have their specificity. So, they have all their personal specificity. The building of a Smart City depends on the main characteristics of its own territories and its managers. I do not think there is a universal model to build a Smart City. (28)

Interviewer: Okay, I think this as well, but I wanted to hear your opinion on it as well. Then, do you notice that there are currently any specific trends for building a Smart City? So, trends that are really hot right now? (32)

Interviewee: You ask me about trends, that is it?

Interviewer: Yes, indeed! Trends for building a Smart City. Over the years, there have been a lot of trends. (32)

Interviewee: I think the best one would be, good collaboration between public managers and local business companies. (32)

Interviewer: So, collaborations between public and businesses? (32)

Interviewee: Yes! (32)

Interviewer: Okay, so then, there are of course big companies like IBM, Cisco and Siemens. In your opinion, what are the big players within the IoT-market right now? So, what companies in the IoT-market are performing very well? (31)

Interviewee: It is a hard question. You mentioned three big companies. These are all the best one in this domain, but I also think that they are in a monopoly situation that give them an advantage compared to others. So, if I have to choose one, I will answer IBM. Because they really specialize in Smart City technologies etcetera. I think we also have to give chance to startups. (31)

Interviewer: Is Nice also collaborating with startups? (30)

Interviewee: Yes, a lot! (30)

Interviewer: Okay, that was actually another question that I had. So, you mentioned the public and private partners a lot already, can you maybe give a few specific examples of public and private partners that helped Nice to become a Smart City? (30)

Interviewee: You would like examples of public and private partnerships?

Interviewer: Yes! If you do not want to mention the name of the companies, it is not a problem, but just so that I can have an indication with what kind of partners Nice is collaborating.

Interviewee: They collaborate with big companies, like for example Alstom, for developing the connected tramway. So, the connected tramway is built on a public-private-partnership. In the domain of energy there are also public and private partnerships in developing smart methods in buildings of Nice. Another example is about all the smart mobility services, existing in Nice. These are all based on public and private partnerships. (30)

Interviewer: Okay, thank you! So, Nice is collaborating a lot there? (30)

Interviewee: Yes. (30)

Interviewer: Okay! Then, I think at this point, all the questions I would like to be answered, are asked. Therefore, I would like to thank you for your time of course.

Interviewee: You are welcome.

Interviewer: Thank you. Then, I have two final questions. Do you wish to remain anonymous in the thesis?

Interviewee: Oh no, it is not important for me to be anonymous.

Interviewer: Okay! I am not sure whether I will use names in the final version, but then I know that. Would you like to receive a copy of the thesis when it is finished?

Interviewee: Yes, I will enjoy reading it!

Interviewer: Okay, nice! Then, I will send it to you when it is finished. So then, thank you for your time and your answers! I wish you a very nice day!

Interviewee: You are welcome. I just want to have one question. Are you beginning your thesis, or are you advanced in it? Is it the first year of your thesis?

Interviewer: This is my Bachelor thesis. In the Netherlands we can do a Master after our Bachelor. So, this is not my Master thesis, but actually my Bachelor.

Interviewee: Okay, good luck!

Interviewer: Thank you very much! Have a nice day!

Interviewee: Have a nice day too!

Interviewer: Thank you! Bye!

Interviewee: Bye!

Appendix 3. Coded Palo Alto transcript

Interviewer: First of all, thank you for your time! I know you are the Chief Information Officer for the city of Palo Alto. Could you maybe explain briefly how this relates to the IoT and Smart Cities? (1)

Interviewee: Sure. You know it is funny that sometimes, when I am giving a talk in San Francisco or to a community group and I talk about the fact that I am a Chief Information Officer (CIO), responsible for technology, one of the things that people quickly react to is: why would a city need a CIO? You know, there is still a great misunderstanding about how cities function and what their needs are. (→ misunderstanding of city needs.) My story that I often share with people, is when I first came to the city, seven years ago. I was invited to speak to a neighborhood group and uhm… Cause Palo Alto is very much a city of neighborhoods. You know, they want to know who I am, they want to get to know me a little bit and I go to the neighborhood meeting and you know, I say: "Hi, my name is Jonathan, and this is what I have been doing. You know, the private sector, I am coming to the public sector to do this" Then, everybody was listening really intensely and then one lady said: "I have a question. Why would a city need a CIO to run a website and an e-mail system?" I said: "Okay, thank you for the question." And it always stood with me, that question. Because from her perspective and she was smart, educated, a person about talent, she understood the city. For her, all the city did, was of course they potholes and they ran a library and cut trees and things like that, but from a technical perspective all she thought is, you know, you just have to have a city website and city email. So, I had two systems. That is basically it. I had to begin the journey to explain and I have been trying to do it now for a few years, that cities are beginning to be some of the largest utilizers of technology. (→ technology in cities) It moved from being sort of an afterthought, about ten years ago, to now being the center of everything. (5 → role of technology in cities) I cannot think of a single project that the city of Palo Alto is doing today where technology is not on the table. (5 → role of technology in Palo Alto) In the city of Palo Alto, we have over 300 different computer systems. If I would have asked you, maybe you would have guessed fifty or something, a hundred, I do not know. We have 300 distinctive systems that run everything from our record management system and public safety for police and fire, to software that helps with medical information in our ambulances. We have a whole array of services and technologies that support our five-library system and on, and on, and on. (5 + 9 + 13 → examples of how technology supports Palo Alto) Of course, you have to have a network and technology. We have to have security software now, because we are, you know. My role is to keep all this going every day. To keep the lights on, keep everything functioning whole as 300 systems need to work. It is not like we stop. It is not like you build a system, you try them on and then everyone is happy. People want more, and more, and more. For example, we have now, I think about 58 new projects for technology, 58! (5 + 13 → role of technology in Palo Alto) For a small city like us and they run and range the whole gambit of potential departments and solutions. Some are inward-facing, in the city organization. Some are outward-facing, they touch community members, visitors and businesses. So, my role is to do all of that. Now, what has happened, over the last few years, is more of the work of the IT organizations, the CIO, has been moving towards the outward-facing technologies. As technology begins to have a bigger role in energy, public safety, transportation, you know, building management, in digitization of services. Moving from analog to digital. Lot of these are now using, you know, more contemporary, more innovative technology. So, the broader sense, any of that could be termed as smart, smart technology and then, by extension, one could argue we have a smart city strategy as a consequence. (5 → shift from technology use) Maybe, we will come back to that point later, because I think that is got to be part of your thesis. What actually is a Smart City and how do you measure that? So, you know, what I have seen as I started with the city, really super-focused internally, making sure all our systems are working and as time has gone by, more of my work is external-facing and that is why, you know as a CIO, I have greater and greater responsibility for our smart city activities.

Interviewer: Okay! Thank you! Indeed, I have this question as well in my thesis. So, what exactly a Smart City is. I found a lot of definitions, so therefore I decided to focus on cities that are really progressive in this field. Because, to be honest, I think there is not yet a specific definition. So, but you mentioned that the IoT and technology, digitalization, is very important for Palo Alto. Would you therefore say that the IoT-based infrastructure can be seen as the backbone for building a Smart City? (6)

Interviewee: That is where you get into this question, what are the prerequisites right? It is going to be just my point of view maybe what you are interested in. I do think that, first of all, a city that is moving progressively forward does have to have fast internet connectivity. So, that means you have to have solid basic infrastructure. That means you got to have fiber, as much fiber as possible. Increasingly, communities are adopting 3G, 4G and soon 5G. Many communities want to have a Wi-Fi. It is not essential, but it is a nice offering. Many cities have city Wi-Fi. That is sort of a prerequisite. (6 + 20 → requirements for cities that are moving progressively forward) Number two, is data management. You cannot be smart if you do not have a data strategy, you do not go for new data. Everything from open data, right through to analytics, visualizations and data-driven decision making. So, data is got to be another major lack of a Smart City. (6 + 20 → requirement for a Smart City) Oh! Getting back to the connectivity piece, many of the trends we are headed in the future, is to "sensorize". It is called "sensorization" of the environment. Where local sensors are distributed across a city architecture for a variety of reasons. Everything from simple things like helping to operate dynamic traffic-signaling systems. So, a small sensor could detect if there is a lot of cars waiting to go through an intersection and there are no cars coming the other way, so you could change the light to green. Security cameras, which obviously more and more proliferate our urban landscape. (32 → trends) So, in order

to have IoT, which seems to be one of the major trends in the Smart City space, you got to have a solid, fast, high-quality core backbone infrastructure. (5, 6 + 20 → trend + requirement for IoT within a Smart City)

Interviewer: Okay. There are certain Smart City components of course. On which components would you say Palo Alto mainly focuses? (8)

Interviewee: Sorry! Say that question one more time.

Interviewer: On which Smart City components would you say Palo Alto focuses the most? So, I know you are doing a lot with smart transportation. (8)

Interviewee: Yeah, I would say… I mean there is a lot. There are four areas, I think that are very active for us. Number one is transportation. (8 → SC component) You got that right. It takes many forms. It is everything from initiatives to encourage people to not drive their car. We are trying to get people into public transport. We are trying to encourage use of bicycles and make available different forms of non-car transport. Scooters are popular now, E-bikes are popular. So that is one category. (9 → How Palo Alto focuses on smart transportation) Staying with transportation for another moment, we definitely want to be a city that supports the emergences of self-driving vehicles. To make sure they are safe, tested and you know, we are doing our part to be a good partner as that movement starts to emerge. The whole autonomous vehicle movement. (11 → objective within smart transportation component) We also want to get people buy electric cars. So, we work our different sort of incentives for that and our different, like promoting why electric cars are a good alternative. So, we have a whole series of technologies and behaviors that we do that are all around the topic of transportation. (9 → How Palo Alto focuses on smart transportation) In many ways, probably that is the biggest Smart City area for the city of Palo Alto right now. (8 → main focused SC component) The second area would be energy. (8 → SC component) One of the things that makes Palo Alto unique in the United States, is that we are one of the few cities that provide all the utilities services. Electric, gas, water, waste water. We even provide fiber internet. So, we have a lot of control over our utility's infrastructure. Many years ago, the city already recognized the need to move to non-carbon-based energy. Move away from, you know, coal and fossils. So, on the residential front, we are now entirely not carbon, which is great. (9 → examples of smart energy) We are quickly moving there on the industry site. So, we can do really interesting things being the sort of owner of the utility infrastructure. So, we are rolling-out smart grid, which is always been one of the more kinds of core traditional Smart City type of infrastructure projects. (9 → smart grid) Now we connect every house in a way that we have rich information to optimize our energy distribution. Also, things like operations and repairs. So, it is a big topic for us. (9 → example of smart energy) Energy would be the second area of smart technology. The third area would be just a broad area of digital transformation. (8 → SC component) You know, since I got here seven years ago, we have deployed over 60 different digital experiences. Everything from permeant applications to reporting apps, crime prevention. Tons of thing that are now done through a web browser or on your smartphone. We continue to do that work. All our signatures are now done digitally. We do not have a lot of paperwork anymore, we digitize all our papers. We do not print as much as we used to. So, a big push on digital transformation and just better services! More efficient, more streamlined, more accurate and more managed services. (9 → examples of how Palo Alto focuses on this SC component) Finally, is our interest in sustainability in the environment. (8 → SC component) In some ways, all the things I have already shared with you are subscenes of that. Energy, transportation and digitization are all parts of the sustainability movement. But it also means managing our water. It also means things like enabling an EV-charger distribution. Putting electric vehicle charging stations all over the community. It means things like water sensors, water management technology. A better understanding about our greenhouse gas emissions. We have a lot of activities related to uhm… You know, again, managing city buildings better. So, that they are energy-efficient. So, I think that are the four big buckets for us. (9 → examples of how Palo Alto focuses on sustainable environment)

Interviewer: I think it is a lot as well. Thank you, very interesting! You mentioned how the IoT and not only IoT, but a part of IoT is enabling the city to become smarter here. Then, I have a bit more of a general question. From your point of view, do you have any general recommendations for cities that want to use the IoT to become a Smart City? So, this could be small cities or cities that never used smart technologies. So, what would you recommend them? (24)

Interviewee: Well… So, the question becomes: Do they need to use the term Smart Cities? One of the reasons why it might be useful is that, you know, it is common language. We are talking about the same thing. It would be difficult to find a city in the world that did not have a technology agenda of some sort. Even a small little village, probably has an e-mail as a server and collects data and stuff. I think cities should not be shy to use the term Smart City. The same time, they get the opportunity to define it any way they like. (→ city defines what a Smart City is) Broadly answering the question though, I do think that we as societies all over the world do need to recognize that technology is going to be at the center of how improve our urban world. We are not going to solve city problems just by behavioral modifications or, you know, by physical infrastructure. (5 → technology to improve the urban world) Increasingly, technology is going to be one of the largest components of how we enable change. (→ technology to enable change) Positive change in the future. So, yeah, I think mayors need to talk with that language. City managers and city leaders need to be talking through the language of positive change through technology. So, leadership is where it begins. That will be one of the first levels of advice I would give. (24 → recommendation/ advice → leadership) Are you as a city…? Do you recognize role and are you being a champion for the effective use of technology to fix some of your issues? That would be the first. Second would be: Well, how do you do that? So, typically, you approach it through the regular budgeting process. Signing more investments in certain areas. Might be difficult for smaller communities. So, you got to look at partnerships. You got to look at ways to collaborate with different stakeholders in the urban ecosystem. (24 → partnerships and collaboration) It might be just about, you

know, city needs, capabilities… So, the city has to find the money and do it. No, I think there are many creative ways now of… There are many different variations of public-private-partnerships to enable this. I am connecting with universities. I am connecting with community members. I am reaching far out. I mean, if you are in a city that maybe, you know, is not tech… That does not have a big tech sector. It does not stop you from reaching out for a city that does, or a community that does. Even if you are on the east coast of the United States, you should reach out to Silicon Valley. Even if you are a smaller city in Germany, you could reach out to other German cities or even other European countries. So, I think the second one is partnerships. (24 → recommendation → partnerships) Now, probably the third would be to have a strategy. Make sure you develop a multi-year strategy that everybody agrees on. Now, strategies change. Strategies are a huge part of what I spend my time on. The worst strategy in the world is: when you do right, you never change. A good strategy is: when you do right, you evolve as circumstances change. So, I will courage cities to have an agreed and articulated technology strategy to support their important goals as a community. (24 → recommendation → strategy)

Interviewer: Okay, thank you! So, you mentioned the academia and to involve others in the Smart City progress as well. Are there any other important factors, next to an IoT-based infrastructure, that are of high importance for building a Smart City? (21)

Interviewee: It feels like I covered most of the points I wanted to make on that topic. I do think you could have a knowledge economy, you could have skills. Make sure you have the right people to execute on that. You could have the best intentions and you could have money, but if you do not have the right people doing the right things, you are not going to get anywhere. (21 → right people have to do the right things)

Interviewer: Okay. So, human capital and smart citizens as well?

Interviewee: Yeah, uhm… I am usually not keen on the smart citizens idea. I would say just human capital to be able to support (21) … I mean, communities are very diverse. I would not limit it to smart members.

Interviewer: Then, those questions were a bit alike. I will pick a different question. How is the IoT-based infrastructure of Palo Alto built up? Does the IoT-based infrastructure of Palo Alto consist of specific layers? (2 + 3)

Interviewee: Uhm… No, it is not that formalized as of now. You got to have a core strong city-wide network infrastructure. You got to be able to manage data across that. It got to be secure. You got to be able to open up your data, so that you can have an ecosystem of participants. You got to have the ability for… I mean, I was going to say infrastructure for sensors, but many communities are just using their lampposts now and their traffic signals. So, those are the physical pieces. Then, you have to have the mindset, the vision, the strategy. Those will be the additional layers on top of it. And the governance! Maybe the piece I have not really mentioned, is the importance of governance. Making sure you are doing the right things at the right time. (2, 3, 20 + 21)

Interviewer: Okay, thank you! Then, another general question. Were there at any point of the Smart City development of Palo Alto problems or obstacles regarding the underlying IoT-based infrastructure? (15)

Interviewee: Everything is an obstacle *laughter*. We face obstacles eight hours a day, every day. Number one in government at cities, is priority. You cannot do everything right. So, the number one obstacle is priorities. You got to make difficult choices. I think that is probably the most important thing, you cannot do everything. There is not enough money, not enough time, not enough talent. So, number one would be, priorities. (15 → priority as most important obstacle for Smart Cities) Number two would probably be talent. We do not have the right people for the work we want to do, or the people we have, need to be trained. Important challenges around talent. (15 → not enough talent as obstacle) Number three of course is the obvious one, money. Many things cannot be done, because they are too expensive. Even through your best tempts to get grants and loans and all the other kind of mechanisms, there is just not enough money to do everything you want to do. So, money would be number three. (15 → not enough money to do everything you want) Number four is leadership. If you have a leader, who is not on board, or you have misalignment of priorities in terms of where a Smart City lands, that is going to be a big issue. (15 → leadership and alignment as a problem) I would say those are the four constraints we face every day.

Interviewer: Thank you. I think this is then a bit of an obvious question, but I would like your opinion on it: do you think there is a best practice for becoming a Smart City? (28)

Interviewee: I think the most important thing is that it is a choice. You have to decide as a city: is this the mission we want to take on? Is this important to our brand? Is this important to who we are? Does this make sense for us? So, I think once you kind of made that decision, everything else is just operational. What do you do? How do you afford it? So, all the operation aspects. The best practice is to make sure that there is a strong supportable vision for it and then execute on it. (28 → It is a choice to become a SC. Strong supportable vision is the best practice)

Interviewer: Thank you. Then, the last question: which public, you mentioned it yourself as well. Which public and/ or private partners helped Palo Alto to become a smarter city? (30)

Interviewee: We have a lot of partners, I mean we have hundreds of vendors. I would actually prefer not to mention a specific vendor. (30)

Interviewer: Okay, I understand.

Laughter

Interviewer: No, I understand. So, then I think that I got a lot of valuable answers. Therefore, I would really like to thank you! I think Palo Alto is doing something really great and it is a very interesting topic to me.

So, therefore, thank you very much for your time! Then, the final question: would you like to receive a copy when the thesis is finished?

Interviewee: Yes!

Interviewer: Okay! So, then I will send it to you! Thank you very much and enjoy your day!

Interviewee: Cool. Well, thank you and good luck with it!

Interviewer: Thank you very much! Bye Bye!

Interviewee: Wait! Where are you? Where ae you?

Interviewer: I am in Enschede at the moment. For the University of Twente!

Interviewee: Aah! I know it well, I know it well. Terrific! See you later, thanks!

Interviewee: See you later! Bye, thanks!

Appendix 4. Coded Stockholm transcript

Interviewer: Let's start the interview. So, the first question: could you explain what your function is and how this relates to the Internet of Things and Smart Cities? (1)

Interviewee: You know Stockholm has established a strategy? A strategy for a smart and connected city?

Interviewer: Yes, I have read it.

Interviewee: To realize that strategy, we started a program on the first of November. Last year and in this program, I am the program manager together with another person. Within this program, we have five different projects. So, those are the projects to realize the strategy. The first project is to establish a platform for establishing data and information. Another project is about open and shared data. They are actually working with the architecture. Those are two projects, but we have three more specific projects. These are: smart locks in the city of Stockholm, smart traffic and also smart and connected lighting. So, those are the five projects within the program.

Interviewer: Okay, then I have another question.

Interviewee: Sure

Interviewer: A Smart City can be divided into a number of different components (e.g. Smart Mobility, Smart Environment, Smart Healthcare, Smart Citizens and Living, etc.). On which component(s) would you say Stockholm focusses the most? (8)

Interviewee: That is a hard question. You know, everyone is talking about smart thing right now. Within our program, we are actually focusing on those three things I have mentioned. Smart locks, smart lighting and smart traffic. Also, to establish a new platform. So, we actually share the data that we get from those three projects. SC components. Sharing data.

[MAIL] *Interviewer:* How is the IoT-based infrastructure of Stockholm built up? (2)

[MAIL] *Interviewee:* Stockholm county has one of the most extended city-owned fiber networks in the world and we are currently reviewing the next steps in our infrastructure portfolio. We are not able to disclose our coming steps, but of course IoT-infrastructure will contain most of the adequate technologies for wireless communication. (2) IoT-based infrastructure build. Wireless communication.

Interviewer: Thank you. Now, a bit more of a general question. Would you say that the IoT-based infrastructure of Stockholm consists of specific layers? (3)

Interviewee: That is a more technical question and therefore, a bit difficult for me to answer. If there are any technical questions, that I cannot answer, you can mail them to me. This way, I can check if they can be answered by my colleagues. But, for the smart lighting, we will change our lampposts. So that we can establish LED lamps there, LED lighting. So, when we do that, it is also possible to have sensors on the lampposts. We will have a pilot project here, to see in what ways we can use sensors. We can have them for changing the light, but we also have sensors for measuring the pollution, wind temperature, etc. When we talk about sensors in traffic, we want to uhm… You know, today, we have sensors in our roads. So, when a car comes close to a traffic light. It is registered that the car is coming, and the light can change. We also try to use cameras that will register the traffic much earlier. So, we can use the real data, to not only see traffic from cars, but also from public transportation, bicycles, pedestrians, etc. So, we have a better view of the traffic situation in the center of Stockholm. But these are all pilot projects. Use of sensors in SC components. Traffic and lighting examples. Use of real data.

[MAIL] *Interviewee:* Yes (3)

[MAIL] *Interviewer:* What types of layers? (4)

[MAIL] *Interviewee:* Our targeted architecture, which includes IoT-infrastructure, is still under construction and we cannot disclose more information at this point. (4)

Interviewer: Okay, thank you. So, then I will email the very technical questions. How important would you say an IoT-based infrastructure is for a Smart City? (5)

Interviewee: I think it is pretty important now! Probably such to say when you work with it. But the reason though we are establishing this, is because we have a lot of challenges. We know that using the smart technology can help us to be a better city for the people that live there, work there and even the people that are visiting us. We have a lot of challenges now. We know that there are a lot of people that need houses and we do not have enough houses actually for the people that want to move into Stockholm. We know that we have a growing aging population. People are getting older and getting retired. Some of these people need help and some of them will have an active life. We would like people to stay in their own homes longer. Smart technology could help us with that. That is also one of the challenges to meet. So, I think saying that smart technologies could be a good thing for the society. Also, when we talk about the air pollution. We need to be a fossil-free city within 2040. There is a big challenge on that part too. Meaning of smart technologies for Stockholm. Smart technologies as enabler.

Interviewer: Okay, that is very clear. Would you therefore say that the IoT-based infrastructure can be seen as the backbone for building a Smart City? (6)

Interviewee: What do you mean with backbone?

Interviewer: With backbone, I mean really if it is without an IoT-based infrastructure, could you then build a Smart City? Or do you need an IoT-based infrastructure, otherwise you cannot build a Smart City? (6)

Interviewee: That is a good question. I never thought about it that way. There is no other part of our infrastructure that we can use to build a Smart City. So, in that case, probably yes. IoT-based infrastructure as backbone.

Interviewer: Thank you. We talked about the smart locks, smart traffic and smart lighting. How does Stockholm use the IoT to become smarter within these components? As in examples. (9)

Interviewee: Well, the thing is that we do not use it right now. We are starting the projects. The project plans are ready, and we just started to establish these. We are in the early mode here. Of course, we did have a lot of tests in different areas, but they are just small tests where we have tried to see if the techniques work. These tests are not as big as the pilot projects. Progress of Stockholm as SC.

Interviewer: Okay, then I understand that it is in the pilot version. I have another question that relates to this. What is the ultimate objective for Stockholm as a Smart City within these components? So, I know the plans are there, but what are you eventually trying to achieve? (11)

Interviewee: Could you ask the question again?

Interviewer: Of course, let me rephrase it. How are you planning on using the IoT to achieve the ultimate objectives within these components? So, for the smart locks, smart traffic and smart lighting. (11)

Interviewee: I think that these three projects that I talked about, those are just the beginning of the new infrastructure that we talked about. IoT is a part of the new infrastructure. Data is the new thing. Using data to establish new services. Actually, it is not the city of Stockholm that should develop all the new services. We will provide the data and then new companies can make new service out of the data we present for them. So, data is the new thing in the infrastructure. I do not think it is just IoT, because we establish data from a lot of different areas. So, IoT is one part where we establish data. Build of infrastructure. Data. Not just IoT as infrastructure. New services by companies.

Interviewer: Okay, I understand. Then, I had a question that relates to this question. So, because you mentioned IoT is not the only thing, would you say there are any other important factors next to an IoT-based infrastructure that are of high importance for building a Smart City? (21)

Interviewee: Maybe not as high as sensors, but you know, in a city we have a lot of information. I think that is one important thing. That is to see that we are doing this for the citizens. Everything we do, is for them. They are the ones paying us for working with it. So, we should actually establish all the data that we can for them to use, if it is possible, new services. But, also to see what we are doing. Are we doing the right thing when we work within the city? So, that is why I think it is also a democratic issue. Aim of Stockholm as a SC. Citizens.

Interviewer: So, because I think citizens are also a factor, would you say that you really include the citizens to build a Smart City together? (21)

Interviewee: Yes! I hope so. When we work with the strategy, we asked a lot of citizens. To see what opinions, they had. So, they were included. Not only citizens, we also asked academia and the businesses. We will continue to do that. Talking with you, is for example one thing. To have academia included in the work. Building a SC next to IoT use. Citizens, businesses, academia.

Interviewer: Yeah, I have read it in the strategy as well. To include citizens, businesses and academia. Something which I also read, is that you received the European Green Capital award in 2010. (8)

Interviewee: Yeah, was is not our CIO at that time? (8)

Interviewer: To be honest, I did not see who received it. It only said that the city of Stockholm received it in 2010 (8)

Interviewee: I did not yet work at this department at that time. (8)

Interviewer: Clear. Do you know if a smart environment and environmental sustainability still is something that Stockholm focuses on? (8) → SC components.

Interviewee: I do not know that. (8)

Interviewer: Okay, then I will pick another question. (8)

Interviewee: Did you say smart environment? (8) → SC components.

Interviewer: Yes! So, smart lighting is also a part of smart environment. (8) → SC components.

Interviewee: I know that they are doing a lot of things, within our environment department, that are close to what we are doing here right now. I do not know about it that much in particular. I heard that they use sensors to measure the water level in lakes and the Baltic Sea. (8) → Use of sensors. Smart environment.

Interviewer: Okay! I also saw that you are constructing a lot of green areas? So, that is also part of smart environment, I guess? (8) → Smart environment.

Interviewee: You know, always when they talk about prices and stuff like that, there are always things that are in the planning stage. You never get those prices when you are done. That is something else which is interesting. So, I really do not know. (8)

Interviewer: Okay, that is no problem. Then, I will look for another question. So, we talked about the IoT-based infrastructure and that is in the pilot face, but could you explain how the IoT-based infrastructure fits into Stockholm's bigger Smart City plan? (14) → Role IoT-based infrastructure for Stockholm as SC

Interviewee: Well, I think this is the big plan. We start out with these five projects to make it possible for other projects to connect. You know, in this strategy, we have seven possibilities. There are seven parts that other projects need to follow. This is the start. We do not have anything else that is bigger than this. The difficult part is actually to follow up and see what other departments are doing. We are talking a lot about the steering component, steering different projects. We have about 50 departments within the city of Stockholm. We need to work more horizontal. Together with the other departments, so that we can cooperate more and see in what way we can find smart solution that not only work for one department, but also for more. That is one of the big challenges when you talk about digitalization. It is a possibility to work more horizontal, than you could before. Cooperate more. Next objective/ next aim. Become more horizontal.

Interviewer: Thank you. What I understand from the answer, is that you are trying to become more horizontal, but are you trying to do this through the IoT-based infrastructure? I guess yes right? (14)

Interviewee: Yes, of course. When we talk about sensors, if I put up ap a sensor from my department, maybe another department would like to use that sensor too to register the same thing. So, in that case we can work together. Let say, an environment department put up sensors, maybe the educational department want to use them in education with the students. This way, they can use real-time data for their students. We also have plans to have the people that live in Stockholm in our planning process. Use of sensors. Cooperation. Real-time data. Include citizens in IoT-based infrastructure.

Interviewer: Okay, thank you. Were there at any point of the Smart City development of Stockholm problems/ obstacles regarding the underlying IoT-based infrastructure? (15) → IoT-based infrastructure problems.

Interviewee: There are a lot of obstacles. This is something new. The first thing we have to find out is a new business model. Who is going to pay for it? That is probably an easy way to solve. People are of course a little bit afraid when we use IoT-solutions. What will happen? Will they be registered? What do we do with personal information? We

have to be aware of the secureness. We have to take care of those issues before we make this big. Obstacles. People are a bit afraid for IoT use. Personal information. Need to be aware of secureness.

Interviewer: Thank you. So, you mentioned privacy and financial problems. Did these problems give new insights about the requirements for Stockholm's IoT-based infrastructure? (17)

Interviewee: I would say, it will give us new insights. We are not there yet, but we know it will give us new insights. New insights.

Interviewer: So, there were no changes yet made to the IoT-based infrastructure because of the problems? (19)

Interviewee: No, we are supposed to solve the problems. We are aware of them and know we have to deal with them. Some of the problems, we know that we will take care of beforehand. We know that we will probably find some problems when we are there, and we have some of the solutions. So, we have to solve these problems at that time. Problems/ obstacles.

Interviewer: So, it is really a continuous process? (19) → continuous process

Interviewee: Yeah.

Interviewer: Okay, then a bit more of a general question. What requirements does an IoT-based infrastructure always have to meet, for cities that want to transform into a Smart City? (20) → Requirement for IoT-based infrastructure.

Interviewee: I think I did not get the question right there. What do you mean with requirements there?

Interviewer: With requirements, I really mean like should an IoT-based infrastructure be this or that? I know it should be interconnected, but is there any other factor of which you say that if an IoT-based infrastructure consists of this factor, there is more chance to succeed for instance?

Interviewee: Could you mail that question as well?

[MAIL] *interviewee:* Adaptability to the city needs is the most important thing. Which means that our strategy is to follow and evaluate new technologies (over time) that could be useful for the city. Of course, new technologies must meet necessary requirements around security. (20) → IoT-based infrastructure needs to be adaptable to the city needs and   secure.

Interviewer: Of course. Then, a bit less of a technical question. How would you say the IoT should be used within an ideal Smart City? So, what role should the IoT have? It is a bit the same, but not as technical as the last question. (23) → Ideal use of IoT

Interviewee: That is also an interesting question. Because I think that there are so many possibilities in a Smart City to use the IoT technology and we are just starting it. I went to a company, last week. One of our telecom companies and we went to their new building. They told us that this new building had about 2.000 or 20.000 sensors in it. Those sensors told them everything about the standard of the building. That is just one way. I also read about another part where they put sensors in the road. Some of the roads in the northern part of Sweden are covered with a lot of ice and snow during the winter. Those sensors could register how much salt there is on the road. The cars that then came, spread salt on the roads, to melt ice and snow, could actually put the right amount of salt on the roads. So, that saved the cars a lot of salt and saved for the companies as well. There are so many ways that we can use sensors. I actually do not know today. Use of sensors (ideal use). SC components. (8 + 9)

Interviewer: Yeah, I understand. It is a very broad question indeed.

Interviewee: I heard about another way where they put sensors in the water faucet. So, they could register how much water they use, and they can also register if anyone had used the water. That was important for the daycare people who are taking care of old people. If they could see that someone had not used the water for ten hours, they came to see if someone had fallen down or if they had not woken up or something like that. (8) Use of sensors. SC components.

Interviewer: Okay, that's a nice technology indeed. I know for instance in my hometown there is a big groundwater level problem. There are often some houses flooded and now they are trying to implement a system that measures the groundwater level with real data. When they see the water is rising, they already start the pumps, in order to prevent floods. So, if we talk about the role of IoT, would it really be an enabling role? So, like, the IoT enables us to find solutions? (23)

Interviewee: Yeah, it will probably give us a lot of solutions. It will help us to solve a lot of problems. We will probably find new solutions and new problems that we have to solve. IoT to solve problems. Enabling role.

Interviewer: Okay, that is clear. Maybe this is a bit of a difficult question as well, because you mentioned there are a lot of pilot stages. Do you have any general recommendations for cities that want to use the IoT to become a Smart City? (24) Recommendations.

Interviewee: My recommendation is to cooperate. To see what other cities do. Learn from international studies and try to look behind and actually talk with people from different cities. It is very easy to say that you are the best or smartest in the world, but what have you done? What is actually new and what good things have you done and actually, what bad things have you done? Wat have not been so good as you thought? In that case we can learn a lot from our own mistakes. Recommendation. Cooperate. Learn from other cities.

Interviewer: Okay, thank you. Do you think every city can transform into a Smart City the same way? So, that there is really a best practice? (26 + 28) → Best practice.

Interviewer: Of course not. In some cases, you need a lot of money to do things like this. I do not know how much small cities you have in The Netherlands, but we do have some really small cities in Sweden. Compared to Norway, these cities are big. Norway has some really, really small cities with just hundreds of people. Of course, if you are such a little city, it is harder to establish things. Anyway, when you establish an infrastructure with IoT, you have to cooperate with the cities among you. We had started that yet, but if we talk about services, like the bike services. This is for people that use their bike every day. To see if it is possible to go the usual way you do. Some of the people in Stockholm have to pass three or four cities, before they arrive to their work. In that case, you have to cooperate to have the same information from all the cities and not just from the city of Stockholm. That is just an example that we have to start to cooperate. No best practice. Different problems in different cities. Recommendation. Cooperate.

Interviewer: Okay, I understand. So, let me see… Are there any public and/ or private partners that helped Stockholm to become a smarter city? I know that you mentioned the telephone company. (30) → Partners.

Interviewee: Yeah, I will say it this way: our part in the whole thing is that in the city of Stockholm, we should establish the data that we can publish. That is our part. The next step is to make the smart services. I hope that should be done by private companies and not by the city of Stockholm. So, that is the next step in this. The first thing is that we establish the sensors and IoT. Then, by using the data from the sensors, we can establish new services. In another way, in the city of Stockholm, we do not develop things by ourselves. Everything we do is within a procurement. So, we procure different solutions, regarding to our infrastructure. We do not develop services by ourselves. So, I cannot say we do this together with Philips or something else, but we do this together with other companies, but we cannot just say: this is something for a certain company. (9) → Data. Role of Stockholm as a SC. New services created by companies. Use of sensors. Solutions regarding to infrastructure (adaptability).

Interviewer: So, if I can conclude, the city really needs these private companies to create the new services. (9) → Companies needed to create new services.

Interviewee: Yeah. (9)

Interviewer: Okay, that is clear. Just in general, not for Stockholm in particular. You mentioned Philips yourself. Companies like IBM, Cisco, Siemens, etc. are big players within the IoT-market. Do you spot any companies within the IoT-market that are performing very well and, in your opinion, offer real solutions for Smart Cities? So, the companies you think are doing well at the moment. (31) → Well performing companies in the IoT-market.

Interviewee: I cannot answer that question. I do not know if there are any companies that are doing something special. Of course, I heard about companies like Microsoft, but I do not know if they are better than others. When we talk about start-up companies that are doing very much in Stockholm, we have a lot of very nice and very developing smart. Usually they are a little bit too small when a city like Stockholm is going for procurement. They are not big enough to develop services that we can buy, but actually they want to do something with other big companies to solve it. Including companies.

Interviewer: Thank you, I understand. I think almost every question is asked, but I have a few more. Actually, I have two more questions. Are there currently any specific trends for building a Smart City? (32) → SC trends.

Interviewee: Yeah, I think there is a big trend right now. Yes, there is! Every city should be smart and everything you do is used and smart. So, that is also a little problem I think to establish a Smart City. Everything you talk about is supposed to be smart. SC trend. Everything is supposed to be smart.

Interviewer: Okay, so you mean that there is a trend that everyone wants to be smart right now and maybe people are not really looking how to do it? (32)

Interviewee: For example, let us talk about smart locks. We have a lot of locks today that are electronic and used all over the world. In our case, that is not a smart lock, but just an electronic lock. A lock that you can open with an iPhone or a code for instance. When you connect that lock to a schedule for the people that are in the elderly care

department and you can get the right person to open a certain door at a certain time, then you have a smart lock. So, that is why you can see the change from a schedule to who should have the ability to open that lock at the right time. That is when we talk about smart. Smart locks. SC components. Definition of smart.

Interviewer: That is very clear, thank you. I think that most of the questions are asked. Therefore, I would really like to thank you for making time for me.

Interviewee: You are welcome!

Interviewer: I think the answers are of high value for my research. So, I have one final question. Would you like a copy when the thesis is finished?

Interviewee: It would be nice to have it.

Interviewer: Okay! Then I will write that down. Do you wish to remain anonymous in the thesis?

Interviewee: No, it does not have to be. If you quote me, it could be interesting to see what you say.

Interviewer: I do not know yet whether I will mention your name, but it could be the case.

Interviewee: That is fine.

Interviewer: Okay! Then I will mail the technical questions and for the rest, thank you very much!

Interviewee: Yeah, you are welcome. It was nice talking to you.

Interviewer: Thank you, I thought so too. Have a nice day!

Interviewee: Thank you! Bye!

Interviewer: Bye! Bye!

Table 3. Analysis of the Results

Part 1 – The IoT-based Infrastructure

Question number	Topic	Nice	Palo Alto	Stockholm
2.	Build of the IoT-based infrastructure	According to Nice, their IoT-based infrastructure consists of specific layers. Further explanation about these layers was not given specifically. However, it was mentioned that public and private partnerships exist within the IoT-based infrastructure of Nice.	Therefore, the IoT-based infrastructure of Palo Alto was stated to be built out of several critical elements. It consists of a strong core city-wide network, with as many fibers as possible. Data flows securely across this network. This includes everything from open-data, to analytics, visualizations and data-driven decision-making. This way, the data is opened-up and an ecosystem of participants exists. According to Palo Alto, a city cannot be smart without a data strategy. Next to that, it consists of sensors that are embedded in	Their IoT-based infrastructure contains most of the adequate technologies that are necessary for wireless communication. They stated to have one of the most extended city-owned fiber networks in the world.

Question number	Topic	Nice	Palo Alto	Stockholm
				physical pieces within the city's architecture.
3.	Specific layers?	Yes	Not necessarily	Yes
4.	Types of layers	Not disclosed	-	Not disclosed
5.	Importance of an IoT-based infrastructure	"An IoT-based infrastructure is important for a Smart City, because it is a way to improve the performance of public services. Today we are living in a digital world. It is really important for cities to use an IoT-infrastructure to develop its services."	"In order to have the IoT, which seems to be one of the major trends in the Smart City space, you got to have a solid, fast, high-quality core backbone infrastructure."	According to Stockholm, an IoT-based infrastructure is very important for Smart Cities nowadays. "The reason though we are establishing this, is because we have a lot of challenges. We know that using the smart technologies can help us to be a better city, for the people that live there, work there and even the people that are visiting us." Overall, the opinion of Stockholm stated that smart technologies are a good thing for society.
6.	IoT-based infrastructure backbone for a Smart City?	"Yes, it is."	"So, in order to have the IoT, which seems to be one of the major trends in the Smart City space, you got to have a solid, fast, high-quality core backbone infrastructure."	"There is no other part of our infrastructure that we can use to build a Smart City. So, in that case, probably yes."
7.	Why?	-	-	-

Part 2 – The Implementation of the IoT

Question number	Topic	Nice	Palo Alto	Stockholm
8.	Focused Smart City components	Mobility, energy and environment Healthcare announced	Transportation, energy, a broad area of digital transformation and sustainability in the environment	Smart locks, smart traffic and smart lighting It was also stated that their environmental department is being active with smart technologies as well and that they are engaging in air pollution. "We need to be a fossil-free

				city within 2040"
9.	Use of IoT to become smarter within components	*See results 4.2!*	*See results 4.2!*	*See results 4.2!*
10.	Examples	*See results 4.2!*	*See results 4.2!*	*See results 4.2!*
11.	Ultimate objective within components	"Nice aims to be a good Smart City in all these components. I would say that Nice would like to be an innovative Smart City, developing these components."	-	"We have about 50 departments within the city of Stockholm. We need to work more horizontal." They now aim to cooperate more among these different departments. By working together, Stockholm wants to find smart solutions, based on real-time data that is gathered from their IoT-based infrastructure. These solutions should not only work for one department, but integrate into other departments as well.
12.	Use of IoT to achieve this	-	-	*See question 11!*
13.	IoT as general enabler to become a Smart City	Use of IoT to digitalize existing services and develop new ones. Therefore, Nice has built up their Smart City concept from an open-data perspective. Use of real-time data and sensors to collect this data.	"We have over 300 different computer systems that run everything." "For example, we have now, I think about 58 new projects for technology, 58!"	"Using data to establish new services." Use of sensors, real-data, open-data, sharing data across different components.
14.	Fit of IoT-based infrastructure in bigger Smart City plan	-	-	Infrastructure is the big plan.

Part 3 – Lessons Learned

Question number	Topic	Nice	Palo Alto	Stockholm
15.	Problems regarding IoT-based infrastructure	"One strength of Nice is, that they build their Smart City concept on the open-data	"Everything is an obstacle. We face obstacles eight hours a day, every day."	According to Stockholm, the first obstacle is a new business model. Find out who is

		perspective." However, in practice, not all data is always accessible. This was stated to be a real problem for the development of IoT-services. Next to this problem, the privacy and acceptance of citizens regarding IoT-services were experienced as important problems. A more general problem was experienced to be the public administration services in Nice. "It is a really bad problem we have in France, the public administration. If IoT-services could improve the process of public administration services, it would be good."	Priority in city governance was named to be the first and probably most important one. Cities cannot do everything and therefore, difficult choices must be made. The second challenge was stated to be talent. In some cases, the right people are not available for the work that must be done, or people need to be trained. "Even through your best tempts to get grants and loans and all the other kind of mechanisms, there is just not enough money to do everything you want to do. So, money would be number three." Leadership was named as the fourth and last constraint. It was stated that big issues will arise, if a leader is not on-board, or when there are misalignments of priorities.	going to pay for it. A more important obstacle was stated to be citizen's security.
16.	How were the solved?	-	-	"We are supposed to solve the problems. We are aware of them and know we have to deal with them. Some of the problems, we know that we will take care of beforehand. We know that we will probably find some problems when we are there, and we have some of the solutions. So, we have to solve these problems at that time."
17.	Did the problems give new insights?	-	-	Not yet

18.	What insights?	-	-	Eventually Stockholm believes insights will come.
19.	Was IoT-based infrastructure changed because of the problems?	-	-	-
20.	Requirements of an IoT-based infrastructure	According to Nice, the first requirement for an IoT-based infrastructure is technology-based. "You need it, to develop the infrastructure in order to implement the IoT." Next to that, the right digital capabilities need to be developed and enough storage space should be available.	*See question 2!*	Stockholm stated that adaptability to a city's needs is the most important requirement for an IoT-based infrastructure. Next to that, technologies that are used, must meet security requirements as described above.
21.	Other important factors, next to the IoT	Other factors that are important for building a Smart City, next to the IoT, were stated to be: management and intention, funding and collaboration. "I think for developing innovations, build on IoT-technologies, we really need to improve the management of ecosystems of these technologies and how we can implement them." Therefore, the right intentions and management of local public actors are needed to build a Smart City. Within all of the focused components of Nice, private and public partnerships services were included. Nice does not only collaborate with big companies, but also	"Then, you have to have the mindset, the vision, the strategy and the governance. Those will be the additional layers on top of it." Next to those factors, human capital was also mentioned as an important factor for supporting the build of a Smart City, next to the IoT.	Apart from the IoT, citizens have a fundamental role within the Smart City development of Stockholm. It was stated that everything the city does, is for them. "When we work with the strategy, we asked a lot of citizens. To see what opinions, they had. So, they were included. Not only citizens, we also asked academia and the businesses. We will continue to do that."

		with local startups. Together with these companies, the city of Nice creates smart solution services. "I think we also have to give chance to startups."		
22.	What factors?	*See question 21!*	*See question 21!*	*See question 21!*
23.	Use of IoT within ideal Smart City	"I would use IoT-services for simplifying public administrations services in Nice. It is a really bad problem we have in France, the public administration. If IoT-services could improve the process of public administration services, it would be good."	-	"There are so many ways that we can use sensors. I actually do not know today."
24.	Recommendation(s)	Nice recommended other cities to assess citizen needs and to include citizens as co-actors within city projects, before developing these projects and corresponding technologies. Next to that, Nice recommended cities to care about citizen's privacy and their acceptance of the use and potential use of IoT-services. "When you use IoT-technologies, you collect a lot of personal and impersonal data and this data is sensitive."	Palo Alto gave three recommendations for other cities. The first one, was that it all begins with leadership. "I think cities should not be shy to use the term Smart City. The same time, they get the opportunity to define it any way they like." City managers and city leaders need to be talking through the language of positive change through technology. The second one, was to look for partnerships. Especially for the smaller cities. According to Palo Alto, there are many creative ways of public and private partnerships to enable this. The third one, was to develop a multi-year strategy that everybody agrees on. "The worst strategy in the world	The recommendation Stockholm gave for cities, that want to use the IoT to become a Smart City, was to cooperate. "When you establish an infrastructure with IoT, you have to cooperate with the cities among you." Stockholm encouraged cities to see what other cities do, learn from international studies, try to look behind this and talk with people from different cities.

			is: when you do right, you never change. A good strategy is: when you do right, you evolve as circumstances change. So, I will courage cities to have an agreed and articulated technology strategy to support their important goals as a community."	
25.	What recommendations?	*See question 24!*	*See question 24!*	*See question 24!*
26.	Can every city transform into a Smart City the same way?	No	It is a choice	No
27.	Why? / Why not?	*See question 29!*	*See question 29!*	*See question 29!*
28.	Best practice for becoming a Smart City?	No	It is a choice.	No
29.	Why? / Why not?	"The building of a Smart City depends on the main characteristics of its own territories and its managers. I do not think there is a universal model to build a Smart City."	According to Palo Alto, every city must decide whether becoming a Smart City is a mission they want to take on. Once that decision is made, the rest is operational. "The best practice is to make sure that there is a strong supportable vision for it and then execute on it."	This was stated to depend on the city itself.
30.	Public and/ or private partners	"Companies use collected data to create new and innovative services." "Nice collaborates a lot with start-ups. They have public and private partnerships. They collaborate with big companies like, for example, Alstom for developing the connected tramway. In the	"We have a lot of partners, I mean we have hundreds of vendors. I would actually prefer not to mention a specific vendor."	"We will provide the data and then new companies can make new service out of the data we present for them."

		domain of energy there are also partnerships in developing smart methods in Nice building."		
31.	Well-performing companies on the IoT-market	IBM	-	"Of course, I heard about companies like Microsoft, but I do not know if they are better than others."
32.	Trends for building a Smart City?	Yes	Yes	Yes
33.	What trends?	"I think the best one would be, good cooperation between public managers and local business companies." So, collaborations between public and businesses.	"Now, what has happened, over the last few years, is more of the work of the IT organizations, the CIO, has been moving towards the outward-facing technologies." (Outward: "they touch community members, visitors and businesses.") "Oh! Getting back to the connectivity piece, many of the trends we are headed in the future, is to "sensorize". It is called "sensorization"	"Everything you talk about is supposed to be smart."