Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Dept. of Industrial Economics and Technology Management

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Smart city development in Nordic medium-sized municipalities

Master's thesis in Industrial Economics and Technology Management
Supervisor: Per Jonny Nesse
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Preface

This master thesis has been written during the spring of 2020 and finalizes a five-year Master of Science program within the Department of Industrial Economics and Technology Management at the Norwegian University of Science and Technology, NTNU. The work of this thesis has been influenced by the ongoing pandemic, Covid-19. Nevertheless, we have gotten through the situation with a positive attitude, and great interest in smart city and ecosystem research. This thesis extends the work in our pre-thesis started in August 2019. Further, the master thesis is part of our academic specialization within the field of Strategy and International Business Development.

The thesis has been carried out with Telenor as a partner. In order to facilitate digitalization in Norwegian municipalities and cities, Telenor has initiated the program ”Smart municipalities and cities”. Their focus on innovating municipalities through technology has inspired the scope of this thesis.

The purpose of the master thesis is to gain practical insights into how medium-sized municipalities strategically manage smart city development in the Nordic. The thesis compare empirical findings to existing literature on the topic and extend the discussion of managing smartness in different contexts. This is done to capture both explicit and hidden assumptions about the effect of smart city development to improve municipal services.

The thesis has an academic approach, but is also written to provide both public and private stakeholders with useful insights into the the complex concept of smart city development in municipalities. We would like to extend our special gratitude to all contributors who have given of their time and shared their knowledge with us in the interviews. We are truly grateful for their cooperation, and this study could not have been carried out without them. We would also like to thank our academic supervisor Per Jonny Nesse and his colleague at Telenor, Ivar Sorkenes, for their guidance throughout the course of writing this master thesis. Finally, our friends and families deserve our appreciation for their continuous support and care during this period.

Executive summary

The aim of this thesis is to provide practical examples and an overall understanding of the state of smart city development across Nordic municipalities. The work brings value and originality by providing empirical findings to a heavily theorized area of research. By interviewing digitalization and smart city leaders in seven medium-sized municipalities in the Nordic region, the thesis describe how smart city development is organized in the Nordic countries and how Norwegian municipalities plan for and utilize Internet of Things (IoT).

The smart city concept has gained interest in the last decade. It is a multi-dimensional and encompass all parts of city development. The aim of smart city development to improve public services and quality of life of citizens, optimize the use of shared resources, increase productivity of cities, and reduce climate and environmental problems by creating more sustainable cities. More and more cities across the world claims to be smart, and several indexes and benchmarks have been created to measure the smartness of cities. However, the concept has first and foremost been described for highly urbanized areas, with less focus given to smart city development in areas with smaller populations, different geographic, demographic, social and economical characteristics. Yet, the implementation of smart technologies which improve municipal services might counteract depopulation, foster growth and create attractive places to live outside the largest Nordic cities.

IoT is one of the main technologies deployed in smart cities and smart municipalities. The potential of IoT lies in its ability to aggregate, merge and analyze massive volumes of data by connecting thousands or millions of sensors and devices. The range of potential application areas for IoT is wast, ranging from health care, waste management, pollution control and drinking water monitoring. Thus, IoT plays a significant role for smart cities.

In a business development perspective, smart city development is an interesting line of research as successful smart city development leads to new business opportunities. The readiness of municipalities to adapt smart technologies will create new business opportunities which can be grabbed at the right time as the smart city development in the municipalities mature.

The master's thesis consists of five introductory chapters and two articles, as well as concluding remarks. The introductory chapters places the scope and results of the articles in the wider context of smart city development and research. Next, the two academic articles outline our empirical findings and how the findings relate to prior research. The abstracts of the articles are presented in the next two paragraphs.

Article 1: Smart city development in the Nordic region
The Nordic countries stand out as digital front-runners in Europe, as well as in a global perspective. However, smart city development in medium-sized municipalities in the Nordic region is less researched than large Nordic cities. Hence, the purpose of this paper is to study how medium-sized municipalities in the Nordic region are organized for smart city

development, and how the development is influenced by contextual factors. Data has been collected through interviews of smart city and digitalization leaders in medium-sized municipalities in Denmark, Finland, Norway and Sweden, as well as secondary data in the form of strategy documents, statistics and reports. The analytical approach is a multiple case study analysis where the selected case municipalities are analyzed and compared in terms of understanding of the smart city concept, smart city governance, resources and collaboration. Our findings indicate that there are great variations in the maturity of smart city development in medium-sized municipalities in the Nordic region. The findings indicate that successful implementation of smart city projects is related to a structured organizational setup, clear goals and strategies, support from a strategic facilitator and focus on project scaling. Further, the findings suggest that the contextual factors of local autonomy, local conditions and the country-level approach to public innovation influence smart city development. The paper provides originality and value by identifying characteristics on how smart city development is organized in medium-sized municipalities across Nordic countries, and how the development is influenced by contextual factors.

Article 2: The municipality's role in a smart IoT-ecosystem
IoT is considered an enabling technology in smart city development. Despite this, there is little to no research exemplifying and analysing the use of IoT for smart city development. Thus, the purpose of this paper is to study how municipalities plan for and utilize IoT in smart city development and how they collaborate with actors in the IoT-ecosystem. Data is collected through interviews of smart city-leaders in medium-sized municipalities in Norway, supplemented with strategy documents, reports and statistics collected online. The analytical approach is a multiple case study analysis where the selected case-municipalities are analyzed and compared by using a smart city-framework adopted for IoT. The findings suggest that the aim of IoT-enabled smart city development is to lower costs and make the municipality an attractive place to live and work. It is found that utilizing IoT is not a goal in itself, but that the technology is seen as a means to reach smart city-objectives. The municipalities strives towards opening up the collected data from sensors and facilitate open innovation with local actors. However, the findings suggest that the IoT-ecosystem for collaboration is complex and difficult to navigate. This paper provides originality and value by providing practical insight into how medium-sized municipalities plan for and utilize IoT in smart city development, how different actors contribute in the IoT-ecosystem and how the municipality collaborate with the different actors.

Despite the thesis' identified challenges related to smart city development in the Nordic region, all Nordic countries have been found to stand out as digital front-runners in Europe, as well as in a global perspective. Hence, smart medium-sized municipalities in the Nordic region seem to be amongst the most advanced municipalities in the World. Thereby, smart city development in Nordic medium-sized municipalities may act as leading examples for smart city development in smaller communities in other countries. In Norway, all the case-municipalities have initiated IoT-projects within multiple municipal services, and their IoT-projects will continue to progress in scale and scope by continuously connecting more devices. Hence, future prospects of smart city development in Nordic municipalities have great potential and may include the use of massive IoT.

Sammendrag

Målet med denne masteroppgaven er å beskrive praktiske eksempler på smartby-utvikling, samt å skape en overordnet forståelse for smartby-utvikling i nordiske kommuner. Arbeidets originalitet og verdi ligger i å fremlegge empiriske funn innenfor et område av forskning som i stor grad er preget av konseptuelle teorier. Gjennom å intervjue digitaliserings -og smartby ledere i syv mellomstore kommuner i norden, beskriver oppgaven hvordan smartby-utviklingen i norden er organisert og hvordan norske kommuner planlegger for og bruker tingenes internett (IoT).

Konseptet smartby har fått økt oppmerksomhet gjennom det siste tiåret. Konseptet har flere dimensjoner og påvirker alle deler av byutvikling. Målet med smartby-utvikling er å forbedre offentlige tjenester og livskvaliteten til innbyggerne, optimere bruken av delte ressurser, øke produktivitet og redusere miljøproblemer ved å skape mer bærekraftige byer. Et økende antall av verdens byer hevder i dag at de er smarte, og flere indekser og sammenlikninger er laget for å måle byenes smarthet. Likevel har konseptet først og fremst blitt brukt til å beskrive urbaniserte områder, og det har vært fokusert mindre på smartby-utvikling i områder med en mindre befolkning og ulike geografiske, demografiske, sosiale og økonomiske karakteristikker. Implementasjon av smart teknologi kan derimot forbedre kommunale tjenester, motvirke fraflytting og skape attraktive steder å bo og leve utenfor de største nordiske byene.

IoT er en av hovedteknologiene som implementeres i smarte byer og kommuner. Potensialet i IoT ligger i teknologiens evne til å aggregere, sammenstille og analysere store volumer av data gjennom å koble sammen tusener eller millioner av sensorer og enheter. Bredden av mulige bruksområder er stor, fra helsesektoren, avfallshåndtering, kontroll av forurensning og overvåkning av vannkvalitet. Dette viser at IoT spiller en viktig rolle for smarte byer.

I et forretningsutviklings-perspektiv er smartby-utvikling et interessant område for forskning fordi det kan lede til nye forretningsområder. Kommunenes modenhet for å ta i bruk nye teknologier vil skape forretningsmuligheter som kan benyttes etterhvert som smartby-utviklingen modner.

Denne masteroppgaven består av en akademisk kappe i fem kapitler, to forskningsartikler og en konklusjon med avsluttende kommentarer. Kappen setter problemstillingen og resultatene fra forskningsartiklene i en større sammenheng med tanke på smartby-utvikling og tidligere forskning. De to forskningsartiklene presenterer de empiriske funnene og hvordan de relaterer seg til tidligere forskning. Forskningsartiklenes abstrakter presenteres i de neste to avsnittene.

Artikkel 1: Smartby-utvikling i norden
De nordiske landene er ledende innen digitalisering i Europa og resten av verden. Likevel er det forsket mindre på smartby-utvikling i mellomstore kommuner enn store byer i de nordiske landene. Derfor er formålet med denne artikkelen å studere hvordan mellom-

store kommuner i de nordiske landene organiserer smartby-utvikling, og hvordan smartby-utviklingen påvirkes av kontekstuelle faktorer. De empiriske dataene er samlet inn gjennom intervjuer av digitaliserings -og smartby ledere i mellomstore kommuner i Danmark, Finland, Norge og Sverige. I tillegg er sekundærdata samlet inn gjennom strategier, statistikker og rapporter. Den analytiske tilnærmingen til problemstillingen er fler-case analyse. De valgte kommunene ble analysert og sammenliknet ved å undersøke deres forståelse av smartby-konseptet, smart city-ledelse, ressurser og samarbeid. Våre funn indikerer at vellykket implementasjon av smartby-prosjekter kan relateres til et strukturert oppsett av organisasjonen, tydelige mål og strategier, støtte fra en strategisk fasilitator og fokus på prosjektskalering. I tillegg antyder funnene at kontekstuelle faktorer som lokal autonomi, lokale forhold og nasjonal tilnærming til offentlig innovasjon påvirker smartby-utviklingen. Artikkelen bidrar med originalitet og verdi ved å identifisere karakteristikker ved hvordan smartby-utvikling er organisert i nordiske kommuner og hvordan smartby-utviklingen blir påvirket av kontekstuelle faktorer.

Kommunens rolle i et smart IoT-økosystem
IoT er en muliggjørende teknologi for smarte byer. Til tross for dette er det lite forskning som eksemplifiserer eller analyserer bruken av IoT i smartby-utvikling. Derfor er formålet med denne artikkelen å undersøke hvordan mellomstore kommuner planlegger for og tar i bruk IoT-teknologi i smartby-utvikling. I tillegg ser artikkelen på hvordan kommunen samarbeider med aktører i IoT-økosystemet. De empiriske dataene er samlet inn gjennom intervjuer av digitaliserings -og smartby-ledere i fire mellomstore norske kommuner, og suppleres med strategidokumenter, rapporter og statistiske data innhentet fra nett. Den analytiske tilnærmingen i artikkelen er fler-case analyse hvor de norske kommunene blir analysert og sammenliknet basert på et smart-city rammeverk tilpasset for IoT. Funnene indikerer at driverne for smartby-utvikling er å redusere kostnader, samt å skape kommuner som er attraktive steder å leve og bo i. Videre viser funnene at bruk av IoT ikke er et mål i seg selv, men et middel for å nå smartby-mål. Kommunene ønsker å åpne opp dataen som samles inn fra sensorer og fasilitere for åpen innovasjon med lokale aktører. IoT-økosystemet oppleves derimot som komplekst og vanskelig å navigere. Denne artikkelen bidrar med originalitet og verdi ved å gi praktisk innsikt til hvordan mellomstore kommuner planlegger for og tar i bruk IoT i smartby-utvikling, hvordan ulike aktører bidrar i IoT-økosystemet og hvordan kommunen samarbeider med de ulike aktørene.

Til tross for at masteroppgaven identifiserer noen utfordringer relatert til smartby-utvikling i norden, er alle de nordiske landene i front sammenliknet med Europa og verden når det kommer til digitalisering. Derfor er smarte mellomstore kommuner i norden kanskje blandt de smarteste i verden. På den måten kan smartby-utviklingen i nordiske mellomstore kommuner fungere som ledende eksempler for smartby-utvikling i mindre lokalsamfunn i andre land. I Norge har alle case-kommunene startet IoT-prosjekter innen flere kommunale tjenester, og prosjektene vil fortsette å vise fremgang i omfang og bredde og kontinuerlig kople på flere enheter. Fremtidens smartby-utvikling har derfor et stort potensiale og kan komme til å inkludere massiv IoT.

Table of Contents

List of Tables

List of Figures

Abbreviations

ICT	Information and Communication Technology
IoT	Internet of Things
LPWAN	Low Power Wide Area Network
LoRa	Long Range - network
NB-IoT	Narrowband - Internet of Things
LTE-M	Long Term Evolution for Machines
QoS	Quality of Service
KL	Local Government Denmark
KF	Association of Finnish municipalities
KS	Norwegian Association of Local and Regional Authorities
SKR	Swedish Association of Local Authorities and Regions
DST	Statistics Denmark
SSB	Statistics Norway
SCB	Statistics Sweden
BN	Business Network

Chapter 1

Introduction

More and more cities across the world claims to be smart, and several indexes and benchmarks have been created to score the smartness of cities. Large cities in the Nordic countries are often represented in the top-tier such smart city rankings. All the Nordic capitals are amongst the top 50 smartest cities in the world (The IMD World Competitiveness Center, 2019; Eden Strategy Institute, 2018). In addition to the capitals, several other large Nordic cities have been represented in the top rankings of European smart cities (Giffinger et al., 2007; European Comission, 2016). In addition, the Nordic countries stand out as digital front-runners in Europe, and are in the top-tier of many digitalization indexes (European Commision, 2019; inCITIES Consulting, 2020; United Nations, 2018). Being a digital front-runner in the contemporary society includes the ability to exploit the potential of smart technologies where smart technologies refers to technologies used to generate value from data and include amongst other; Internet of Things(IoT), 5G and cloud computing (Lemke et al., 2020).

However, even though the Nordic countries stand out as digital front-runners at a country level, few studies have examined municipal smart city development in the Nordic countries. Existing research on smart city development in the Nordic countries includes a framework to evaluate and adjust smart city metrics to arctic and remote locations (Raspotnik and Herrmann, 2020), and a framework to evaluate governance structures of smart city initiatives in three medium to large-sized cities in Norway (Gohari et al., 2020). According to Gohari et al. (2020), Norwegian municipalities in particular have begun following a smart city approach in which digital technologies are enablers of smart city solutions. In addition, Norway is built on values of transparency, inclusion, equality and the society model reflect these values and provides citizens with good social welfare and closeness to power. The Norwegian public sector also have traditions for collaboration across sectors (Design and Architecture Norway (DOGA), the Norwegian Smart City Network, Nordic Edge, 2019). The digital infrastructure in Norway consist of a well-developed fourth-generation (4G) mobile network, covering almost every rural area and part of the elongated country (Doga et al., 2019). Further, a prioritized area for the Norwegian Government is to deploy a nationwide 5G network to better leverage the opportunities the network provide related to smart technologies, such as Internet of Things (IoT) (Ministry of Local Government and Modernization (KMD), 2020). This set of enabling factors is what the Norwegian Smart City Network calls the 'Norwegian smart city model' (Doga et al., 2019). Doga et al., 2019 see these factors as important building blocks and platforms for the development of smart and sustainable public services that can be scaled and exported.

Despite the sovereignty of the Nordic countries in terms of smart city potential and development, there are no studies to our knowledge which comprehensively and empirically study how smart city development is performed in Norway or any other Nordic country or municipality. To fill this research gap, we have performed two multiple case studies. The aim of these studies is to both test the validity of existing theory, and add to existing theory based on our empirical findings. The findings are presented in the form of two individual academic research papers. The first article focuses on the Nordic region and aims to create an understanding of the state of smart city development in the selected Nordic municipalities. The second article more specifically regard Norwegian IoT-enabled smart city development and the corresponding IoT-ecosystem. The following research questions is proposed and are answered in the two articles:

Article 1:
Smart city development in Nordic medium-sized municipalities

Research question:
How is smart city development organized in medium-sized municipalities in the Nordic region?

Article 2:
The municipality's role in a smart IoT-ecosystem

Research question 1:
How does the municipalities plan for and utilize IoT in smart city development?
Research question 2:
How does the municipality collaborate with actors in the IoT-ecosystem?

Through the articles, this master thesis aim to provide practical examples and an improved overall understanding to the state of smart city development across Nordic municipalities. The work provides value and originality by providing empirically findings to a heavily theorized area of research. The articles discuss how contextual factors such as local conditions affect smart city development in municipalities in the Nordic region and how IoT-projects affects the smartness of medium-sized municipalities in Norway. By including collaboration in the research questions, the findings should have relevance to a series of actors outside the municipality sector, and may serve as a collection of guiding perspectives. Further, both theoretical concepts and empirical background are described in detail, to serve as a theoretical and informative basis for the empirical findings in this thesis.

1.1 Guide to the reader

The thesis is structured into eight chapters. The first chapter, presents the methodology for sampling relevant academic articles and documents. It provides an overview of the case municipalities and outline the methodical limitations of the thesis. Next, chapter three present relevant academic literature within the filed of smart city, smart city governance, innovation ecosystems and inter-municipal collaboration. Chapter four present IoT as a smart city enabler and gives a brief description of the technological aspects of IoT in general. Chapter five provides an overview of relevant contextual factors for smart city development in the Nordic countries. Further, chapter six present the article ”Smart city development in Nordic medium-sized municipalities”. This chapter is followed by chapter seven, presenting the article ”The municipality’s role in a smart IoT-ecosystem”. Both articles aim to be published in a scientific management journal at a later stage. Finally, chapter eight finishes off the master thesis by presenting our concluding remarks with regards to theoretical implications and areas for future research.

Chapter 2

Method

The research design of this thesis consists of sampling of academic literature, sampling of secondary literature from practitioners and two multiple case studies based on interviews with digitalization -and smart city leaders of seven Nordic municipalities. In this chapter we present the methodology for the sampling of academic articles and secondary literature, while the methodology of the multiple-case studies are described in detail in the articles following in chapter 6 and 7. The aim of sampling academic literature is to establish a broad theoretical basis which places the empirical findings in the relevant context, while the secondary literature from practitioners supplement with relevant background information on IoT and contextual factors influencing smart city development. In addition to the methodology for sampling literature, this chapter provides an overview of the case-municipalities and outlines the overall methodological limitations of the thesis.

The total of 110 academic articles, reports, indexes, web-pages and statistical sources were collected for this paper. In this sample, 51 sources are academic articles, while 59 sources are secondary literature from practitioners. In addition to this sample, the web pages of the municipalities, as well as reports and documents describing specific smart city projects in the specific case-municipalities have been read. However, these documents has not been included in the reference list in order to maintain the anonymity of the cases.

2.1 Sampling of academic articles

The theoretical foundation of this thesis has been collected through three methods. First, this thesis builds upon literature from the systematic search performed in our pre-thesis from fall 2019, a database search performed spring 2020 for literature adjusted to the research questions of this thesis, and backwards snowballing of relevant articles from the database search. Figure 2.1 provides an overview of the distribution of the academic articles from the different methods. Further, the distribution of articles on year is shown in figure 2.1. The distribution of articles on publishing year is shown in figure 2.1. The figure shows that most of the sampled articles are recently published. However, articles published before 2016 were included if they represented state-of the art conceptualizations, definitions or if more recent literature do not describe the topic.

In total 24 articles from our pre-master's thesis has been referenced in this thesis. The

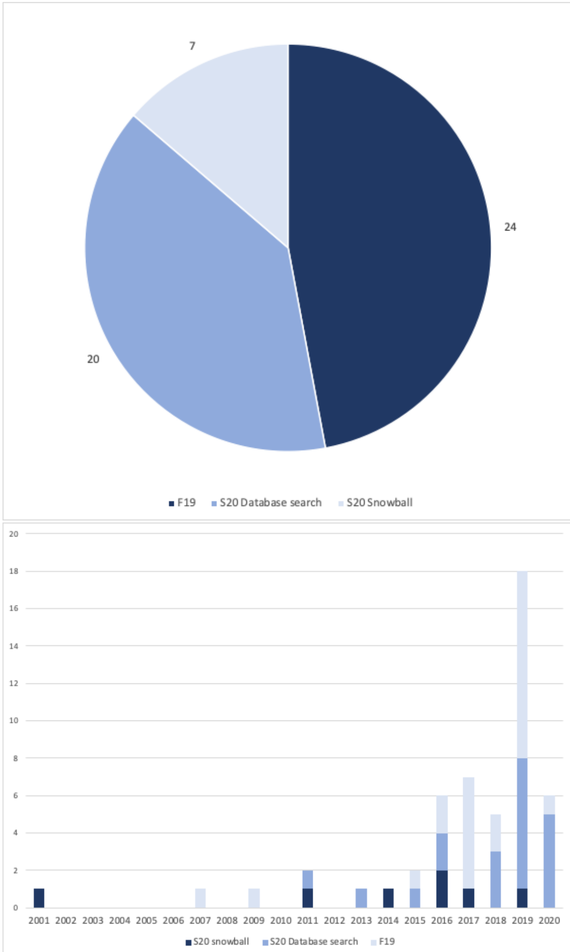

Figure 2.1: (Top)The distribution of articles from pre-master's thesis (F19), database search for additional literature and snowballing. (Bottom) Distribution of articles on publishing year.

systematic search in the pre-thesis was related to the topics public business models, e-government, ecosystems and IoT utilization in public sector. The topic of research in the pre-thesis was to collect the literature findings regarding how digitalization in medium-sized municipalities are organized and how municipalities can capture value from IoT. Because, the scope of this master's thesis is more focused towards smart city development, we needed to further search for literature on this topic.

The database search for smart city literature was performed in the databases Scopus and Google Scholar in order to retrieve the most relevant articles. Several keywords where tried and the search terms (2.1) and (2.2) proved to return the most relevant articles. Search term (2.1) was used predominantly to collect articles which could provide relevant theory on how smart city development is organized. Whereas the aim of the search term (2.2) was to collect articles related to the characteristics of municipalities utilizing IoT and the related innovation ecosystem. It is further important to state that smart city, innovation ecosystems and IoT are somewhat overlapping topics. Hence, some of the articles sampled proved relevant for both articles. In total the database search resulted in 20 articles.

$$\begin{aligned} ''(Smart\ city\ OR\ Smart\ governance\ OR\ Smart\ government) \\ AND \\ (Contextual\ factors\ OR\ (Size\ OR\ Rural\ OR\ Small))'' \end{aligned} \tag{2.1}$$

$$\begin{aligned} ''(Innovation\ Ecosystem\ OR\ Citizen\ participation \\ OR \\ (Collaboration\ AND\ municipality)) \\ AND \\ (IoT\ OR\ Internet\ of\ Things\ OR\ smart)'' \end{aligned} \tag{2.2}$$

In addition to the database search, backwards snowballing was performed. As for the articles from the database search, articles from snowballing was included based on their relevance to how smart city development is performed and planned for, or the use of IoT in municipalities. In total 7 articles from backward snowballing were included in the sample.

Further, all relevant articles have been categorized based on the main topic in the article. Table 2.1 provides an overview of the groupings. Smart city is the main topic in 27 of the articles, where 24 of the articles were sampled from the database search and snowballing of spring 2020. Innovation is the main topic in 7 of the articles, whereas IoT is the main topic of 14 articles. For both innovation ecosystems, inter-municipal collaboration and IoT, most of the articles were sampled from the pre-thesis.

2.2 Sampling of secondary literature from practitioners

In addition to the sampling of academic articles, we have collected practitioner literature in the form of reports, webpages, digital and smart city indexes and statistical data. An overview of the collected practitioner literature is shown in table 2.2.

Reports, statistics, webpages and strategies describing relevant aspects of the Nordic context were collected to understand the country-level dynamics under which the municipalities in each country operates. The sample of reports describing the Nordic context include reports on urbanization and demographic structure in the countries, the local autonomy of the municipalities, how the roles and responsibilities of digitalization is organized between the different levels of government in the Nordic countries, how innovation is approached in the public sector and reports on the state of smart city and digitalization. In addition to reports mapping the state of digitalization, the country-level strategies for digitalization in

Table 2.1: Grouping of main topic of articles and the number of articles in each group.

Main article topic		**Number of articles**	**Articles sampled spring 2020**
Digitalization		1	0
E-government stage model		2	1
Smart city	*Smart city concept*	6	6
	Smart government	2	2
	Smart city governance	5	5
	Smart city ecosystem	3	3
	Smart city size	7	3
	Contextual factors	2	2
	Citizen participation	2	2
Innovation	*Innovation ecosystems*	4	1
	Intermunicipal collaboration	3	1
IoT	*Public business models for IoT*	4	0
	IoT technological aspects	7	1
	IoT applications	3	1
Total		**51**	**27**

municipalities were included in the sample.

Further, a set of digital and smart city indexes were included in the sample in order to benchmark the state of smart city development and digitalization in the Nordic region compared to Europe and worldwide standards.

In addition the documents describing the Nordic context, a set of IoT reports and network reports, as well as webpages were included to map the deployment of the technologies in the Nordic region. These were also included to get up-to-date industry information on the current state of IoT and the related LPWAN-network technologies.

Most of the secondary literature from practitioners were found by database searches. In addition, some of the reports were provided to us by supervisor, Per Jonny Nesse.

2.3 Overview of case-municipalities

The method for selecting cases, collecting empirical data and analyzing the data is described in detail in the methodology sections of two academic articles attached in chapter 6 and 7. Thus, this section will provide an overview of the empirical data of the articles overall. For the first article, one case-municipality was selected from each of the countries Norway, Denmark, Sweden and Finland. For the second article, four Norwegian case-municipalities were selected. Further, as seen in table 2.3, one of the Norwegian

Table 2.2: Type and number of secondary documents collected.

Type of document	**Number of documents**
Reports on the Nordic context	16
IoT and connectivity reports	6
Digital and smart city indexes	6
Digital index method	2
Webpages on the nordic contex	7
IoT and connectivity blog posts, web pages and white papers	9
Public Digitalization strategies	5
Population statistics	4
Municipal size definition	4
Total	**59**

case-municipalities was used as a case-municipality in both articles.

Table 2.3: Overview of cases.

Country	**Case code**	**Article 1**	**Article 2**
Norway	M1		
Norway	M2		
Norway	M3		
Norway	NM, M4		
Denmark	DM		
Finland	FM		
Sweden	SM		

General notes on the case-municipalities

Due to the complexity and variety of municipal size definitions, the size criteria for medium-sized case municipalities in this thesis is defined to be population size of 20 000 - 60 000 inhabitants. The size interval is set to include case-municipalities which are large enough to have initiated their own smart city projects, but small enough to have different demographic, social and economic characteristics than larger cities.

One or two digitalization or smart city leaders in the municipalities were interviewed. In addition, municipal websites, reports and articles which mentioned the case-municipalities were scrutinized in order to supplement the findings from the interviews. Note that in order to maintain the anonymity of the case-municipalities, the secondary data sources linked to specific municipalities are not included in the sample of secondary literature from practitioners presented in section 2.2.

The two interview guides for the Norwegian cases and the Nordic cases slightly differs. The interview guide used when interviewing the smart city leaders in the Norwegian countries can be found as an appendix to article 2, while the interview guide used when interviewing smart city leaders in the Nordic countries can be found in appendix for article 1. For the Norwegian case-municipality which is a part of both article 1 and article 2, the Nordic interview guide was used.

2.4 Methodological limitations

This section presents the methodological limitations of the thesis. According to Yin. (2014), four tests can be performed in order to assess the methodological limitations of case studies. These four tests are correct interpretation of concepts (construct validity), establishment of causual relationships (internal validity), the domains to which the study is generalizable (external validity) and repeatability of the study (reliability).

In terms of construct validity, theoretical understanding of concepts and language poses possible limitations. Smart city and IoT have become buzzwords which have multiple understandings. One limitation to this study is that interviewees and the interviewers sometimes had a different understanding of theoretical concepts. In example, the interviewees had a broader definition on what is considered smart city projects. Further, interviews of representatives from the Danish, Finnish and Swedish municipalities were conducted in English which is neither the native language of the interviewers nor the interviewees. According to (Yin., 2014), triangulation, the use of multiple sources of evidence increase construct validity. Hence, municipal websites, reports and articles that mentioned the case-municipalities were scrutinized in order to supplement the findings from the interviews.

Additionally, to multiple understandings of the smart city concept, there exist multiple definitions of municipal size. Appendix A provides an overview of the municipal size definitions of each of the countries Norway, Sweden, Denmark and Finland. The overview shows that each country has their own definitions of size, using multiple different metrics. For this thesis, we chose population size as the only size metric, and defined medium-sized municipalities to population size of 20 000 - 60 000 inhabitants. Hence, a limitation to this study might be that the size interval not completely correspond to the countries' own definitions of municipal sizes.

Further, internal validity can be ensured by triangulation Yin. (2014). For this thesis, triangulation was used both when sampling academic articles, documents from practitioners and in the interview process. In terms of validity of the sampling of academic articles, multiple articles on each of the theoretical concepts where sampled. However, in some cases, the literature on the concept is scarce, leading to a limited number of articles. Further, to ensure validity of the sampling of documents from practitioners, multiple data sources were used to describe each topic. Last, validity of the empirical data was ensured by supplementing the data from the interviews with data from municipal websites, reports and articles which mentioned the case-municipality. Further, follow-up questions were sent to the municipalities after the interview in order to clarify elements of uncertainty. Out of the seven municipalities, six responded to this email. For the Norwegian cases, a list of IoT-projects as well as their scope and area of application was sent to the municipalities for them to confirm.

It is challenging to ensure external validity of case studies, due to the small sample of cases. However, analytical generalization, generalize to concepts and propositions rather than samples or populations is a possible measure that can be taken to increase external validity. In order to increase the external validity of this study, the empirical findings from the study have been discussed and compared to existing theory and case studies in the literature. Further, the cases was selected both on unifying criteria (in example, examination of municipalities being the same size), and diversity across context criteria (Stake, 2013) (in example, examination of municipalities in different countries). These factors increases the external validity within the context of the case-selection criteria.

Complete reliability, as the possibility of exact replication of this study under the same circumstances, is almost impossible. However, some measures have been taken in order to increase the reliability. First, the methodology aim to provide transparency of the sampling of academic articles and literature from practitioners. Second, the methodology-sections within the two articles provide transparency in respect to the case selection, data collection and data analysis. Further, the interviews were conducted based on interview guides, making it easier to replicate parts of the study.

Chapter 3

Theoretical background

This chapter presents the theoretical foundation for this thesis. The theoretical concepts are later applied in the analysis-parts of the articles for answering the research questions, and in the discussions to support contributions and implications of the empirical findings. The main research streams presented in this thesis is smart city literature and literature on innovation ecosystems. First, the concepts of digitalization, smart government, smart municipality and smart city is defined and linked to each other. Next, the dimensions and dichotomies of the smart city concept is elaborated upon. Then, relevant literature on smart city governance and innovation ecosystems are presented and linked to smart city development in municipalities. Last, existing literature on inter-municipal collaboration in the context of digitalization and smart city is presented.

3.1 Linking and defining digitalization, smart government, smart municipality and smart city

Digitalization is a broad concept which describes the phenomena and processes of adopting and using digital technologies in broader individual, organizational and societal contexts (Urbach and Röglinger, 2019). Due to the broad definition of digitalization, the term e-government or smart government more precisely define digitalization in a public context. The e-government concept describes how information and communication technologies (ICT) is used to support public duties efficiently and effectively (Wirtz and Daiser, 2015). As the government modernize and adapt new technologies, it advances towards becoming a smart government. These advancements are described through the e-government stage model (Layne and Lee, 2001; Lemke et al., 2020).

The stages of an e-government are (1) the publishing information stage, (2) the transactional stage, (3) the integrative stage, (4) the horizontal stage, and (5) the providential stage (Layne and Lee, 2001; Lemke et al., 2020). In the first stage, the government publish and provide information to its citizens online. Next, the transaction step includes digital user interaction with citizens, in example online registration or payment of services (Chen and Kim, 2019). The transactional stage includes linking local systems to higher level systems within similar functionalities. While e-governments with horizontal integration integrate systems across different functions which enables information obtained by one agency to propagate through all government functions (Layne and Lee, 2001). The transactional stage also includes open government data, digital complaint management, collaborative project systems and electronic consultation of public stakeholders (Wirtz and Daiser, 2015). In the providential stage, the government becomes data-driven and able to proactively use and deliver information to citizens. It is only in the providential stage that the e-government becomes a smart government.

The smart government takes the step beyond past digitalization endeavors, ”asking how the relationship between administration and its stakeholders could be implemented in more efficient, effective, and/or unexpected ways using sensors, big data, and personalized algorithms ”(Guenduez et al., 2020, p.191). Examples of technologies used are Big Data Management, the Internet of Things (IoT), sensor networks, smart devices, embedded systems, 5G and cloud computing technologies (Lemke et al., 2020). For the smart government it is mandatory to rethink the ways governments operate for smart initiatives to have impact, be effective, and establish seamless information flow and collaborative decision making (Guenduez et al., 2020).

For this master thesis it is also useful to define the term smart municipality. The smart municipality can be seen as a type of smart government with administrative responsibility of local public services. The smart government and smart municipality concept is also strongly related to the smart city concept, and some scholars view smart city as a subset of the broader concept, smart government (Ooms et al., 2020). A smart government is able to do smart city development, where smart city is an area for collaboration and service co-production and testing (Anthopoulos and Reddick, 2016).

3.2 The smart city concept

The aim of this master’s thesis is, as previously mentioned, focused towards smart city development in medium-sized municipalities. However, research so far has predominantly been focused on cities, leaving towns and rural areas behind (Hosseini et al., 2018). Nonetheless, conceptual research on smart cities provide an overview of the concept. Thus, because no coherent definition of smartness in rural areas exist, the general definition of a smart city is used as a starting point. Multiple authors have tried to define the smart city concept. This thesis present two well-cited definitions. First, a smart city...

> ”...generally refers to the search and identification of intelligent solutions, which allow modern cities to enhance the quality of the services provided to citizens”. (Giffinger et al., 2007, p. 11).

Additionally, the aim of a smart city is to...

> “...provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration amongst different economic

actors and to encourage innovative business models in both private and public sectors" (Appio et al., 2019, p.1).

In addition to the general definitions, the literature describes multiple perspectives or frameworks which further elaborate on the concept. The literature review of this thesis identifies both frameworks describing the dimensions or elements of a smart city (Giffinger et al., 2007; Bedford et al., 2011), as well as frameworks focusing on describing dichotomies or opposites in smart city development (Angelidou, 2014; Mora et al., 2019). The next paragraphs will further explain the different smart city perspectives.

First, a smart city is well-performing according to the following six dimensions: smart economy, smart people, smart governance, smart mobility, smart environment and smart living. In order to measure the smartness of a city or municipality, Giffinger et al. (2007) have identified a set of factors which characterizes each dimensions. All the dimensions have a clear focus making them distinguishable from each other, the factors presented in figure 3.1 further specify the characteristics of the dimensions. First, the smart economy dimension is focused towards competitiveness, productivity and innovative spirit, describing the ability of the city to transform. Next, the smart people dimension is centered around the flexibility, creativity and level of qualification of the citizens and measures the level of social and human capital in the society. Further, smart governance includes the political and strategic perspectives of the city. The smart mobility dimension enhances sustainable, innovative and safe transport systems. Smart environment focuses on pollution and sustainable resource management. Lastly, smart living enhances the quality of life of the citizens including health conditions, education and cultural facilities (Giffinger et al., 2007).

Smart Economy
(Competitiveness)
- Innovative spirit
- Entrepreneurship
- Economic image and trademarks
- Productivity
- Flexibility of labour market
- International embeddedness
- Ability to transform

Smart People
(Social and Human Capital)
- Level of qualification
- Affinity to life long learning
- Social and ethnic plurality
- Flexibility
- Creativity
- Cosmopolitanism/ Open-mindness
- Participation in public life

Smart Governance
(Participation)
- Participation in decision-making
- Public and social services
- Transparent governance
- **Political strategies and perspectives**

Smart Mobility
(Transport and ICT)
- Local accessibility
- (Inter-)national accessibility
- Availability of ICT-infrastructure
- Sustainable, innovative, safe
- transport systems

Smart Environment
(Natural resources)
- Attractivity of natural conditions
- Pollution
- Environmental protection
- Sustainable resource management

Smart Living
(Quality of life)
- Cultural facilities
- Health conditions
- Individual saftey
- Housing quality
- Education facilities
- Touristic attractivity
- Social cohesion

Figure 3.1: The six dimensions of a smart city and the related factors (Giffinger et al., 2007)

Second, Bedford et al. (2011) has created a five-level pyramid, which describes the dependence of one smart city element on another. The two first elements comprises the basis of smart city development and needs to be present in order to further create the smart city. The basic elements are the physical areas of the city, such as buildings, parks and public spaces, and the city infrastructure including network deployment, energy and water. The top three levels includes collaborative ecosystems, applying technology in smart city services and living.

Angelidou (2014) and Mora et al. (2019) are more focused towards the opposites existing in smart city research. Angelidou (2014) reviews factors which differentiates policies for smart city development. The paper identify four types of strategies and present related advantages and disadvantages. The strategies examined are; national versus local strategies, new versus existing city strategies, hard versus soft strategies and sector-based versus geographically based strategies. The national versus local strategies perspective discuss the applicability of nationally and locally created strategies. The next perspective discuss the differences of smart city development in new versus existing cities. ”New” cities refer to cities built from scratch and is mainly a trend seen in developing countries. Hence, this perspective is considered a special case not applicable to the research of this thesis. The third perspective, hard versus soft strategies ”refers to whether the smart city strategy will target the efficiency and technological advancement of the city’s hard infrastructure systems (i.e. transport, water, waste, energy) or the soft infrastructure and the people of the city (i.e. social and human capital; knowledge, inclusion, participation, social innovation, social equity, etc.).” (Angelidou, 2014, p.S5). The last perspective, sector based versus geographically based strategies, differentiates between strategies aiming at transforming specific economic sectors of the municipality, and strategies aiming at improving geographically determined clusters such as business districts, research and development clusters and even neighbourhoods.

The other framework focusing on the opposites of smart city development, are the four dichotomies of Mora et al. (2019). Through an extensive literature review, Mora et al. (2019) have identified that smart city research is diverging into four main dichotomies: techno-led or holistic, top-down or bottom-up, double or triple/quadruple helix, and mono-dimensional or integrated. Mora et al. argue that these four opposing smart city focuses ”exposes hidden contradictions of the smart city debate” (Mora et al., 2019, p.94), by considering the related aspects of smart city development coherently.

The first identified opposing smart city focus is the technology-led or holistic smart city view. It refer to the different research streams that either find that smart city development is best driven by focusing on the available technology or the other view, that state that technology-led view is inadequate to support smart city development because it does not take the human, social, cultural, economic, and environmental factors into account (Mora et al., 2019). What primarily separates these views is the degree to which the city focuses on citizen participation (Berntzen and Johannessen, 2016) and community building. The second dichotomy focuses on the differences in how smart city-strategies should be formed and organized. Some strategies have a top-down approach in regards to strategy formation, where the long-term vision and strategic frameworks are formed at higher governmental management level. Whereas the bottom-up approach is more deregulated, based on self-organization and driven on grassroot movements. To see what view a city has, one can study the strategy documents and see how smart city development is organized. In example, a work group dedicated to smart city at a local level acts as an indication to a bottom-up approach.

The third opposing smart city focus comprises the two research streams that present the required focus areas for implementing smart city development strategies. Researchers such as Giffinger et al. (2007) have found that smart city strategies should have a multi-dimensional approach, covering a large number of application areas and policy domains. While other researchers, like the European Commission, promotes smart city strategies that cover few application areas and municipal sectors (Mora et al., 2019). The last dichotomy address the differences in smart city research among those studied that solely focus on public-private collaboration and those arguing for a triple or quadruple helix model of collaboration. The fist view suggest that collaboration is limited to the interaction among service providers selling their smart city solutions and the local government. However, the largest stream of research stress the importance of collaboration based on a triple or quadruple-helix model, where all city stakeholders are represented (Mora et al., 2019).

3.3 Smart city governance

As previously mentioned, smart city governance is one of the six dimensions identified by Giffinger et al. (2007). However, (Ruhlandt, 2018, p.1) argue that "research on smart cities lacks a systematic understanding of the different components of smart city governance, the metrics to measure these components, their envisaged outcomes and potential contextual factors influencing both components as well as outcomes". Additionally, Lee et al. (2014) identifies smart city governance as an important driving force for smart city development, arguing that the governance mechanism of a city bring together the stakeholders "in driving growth and adaptability and fostering a broad take-up of smart services" (Lee et al., 2014, p.86). Further, the smart city governance dimension has gained interest in recent studies as it focuses on the decision-making processes, control of development initiatives, and project priorities of smart city development (Gohari et al., 2020). By this means, smart city governance places importance on the inter-relations among the participating actors in the smart city ecosystem.

Lee et al. (2014) have developed a framework for case study analysis of smart city initiatives focusing on the process building for effective smart cities. The authors also applied the framework on two cases. The empirical findings from these cases suggest that effective and sustainable smart cities emerge as a result of actors from public and private sector coordinating their activities and resources on an open innovation platform. In this process, the city's governance mechanisms act as a driving force, bringing together the actors involved. Further, six governance mechanisms were identified as important elements in order to succeed with smart city development. The mechanisms where: (1) smart city leadership by the mayor's office and the leaders of the municipal departments, (2) a formal and comprehensive smart city strategy, (3) a dedicated smart city team in the municipality, (4) standard planning and development processes, (5) smart city principles adapted by the municipal departments and (6) smart city performance criteria defined and used by the city agencies. In summary "one of the study's key findings is that the form of smart city governance set up in the early stages of planning had a significant effect on the range and maturity of services the cities had been able to put in place" (Lee et al., 2014, p.95).

Ruhlandt (2018) takes a somewhat broader perspective on smart city governance, and performs an extensive literature review on the findings from a broad number of smart city governance papers. The literature review groups previous literature on smart city governance into four broad research subjects; components, measurements, contextual factors and outcomes. Further, each broad subject identifies multiple sub-categories of smart city governance. The identified smart city governance components are, stakeholders, structures & organizations, processes, roles & responsibilities, technology & data, legislation & policies and exchange arrangements. Further, Ruhlandt (2018) found that few studies have examined measurement of smart city governance or the contextual factors influencing smart city development. Measurement refers to techniques for measuring the effect of the different smart city governance components. While the contextual factors refers to external factors which might have an influence on smart city development. The identified contextual factors where local autonomy and local conditions. Local autonomy refers to the degree of organizational freedom when it comes to decision making in the municipality or the city, while local conditions refers to local political, demographic, economic or social characteristics. Lastly, the outcomes of smart city development can be identified as either substantial outputs or procedural changes. The substantial outputs focus on the direct consequence of the implementation of smart city governance such as economic, environmental or social metrics. The procedural changes on the other hand focus on the behavioral and procedural changes in the implementation.

Recent papers, published after the extensive literature review of Ruhlandt (2018), further elaborate on the governing of smart cities (Ooms et al., 2020; Gohari et al., 2020; Argento et al., 2019). Ooms et al. (2020) illustrate how elements of governance structures in smart city ecosystems evolve over time and "how these elements enable or inhibit the success of such ecosystems in different phases of evolution" (Ooms et al., 2020, p.1). Further, (Gohari et al., 2020, p.1) explores the connection between governance and smart cities by "examining the actors, processes, and relational mechanisms at different levels that have had an impact on the initiation of smart cities in three Norwegian cities". By taking the governance perspective on smart cities, Gohari et al. were able to illustrate the structural sources of the interests, roles and power in smart city initiatives, and showed that it affected the goals designed by the specific actors. Argento et al. (2019) on the other hand explores the role of performance measurement systems in the operationalization of a smart city program. The aim of the study was to answer how the development and use of performance measurement systems support smart cities in order to achieve their goals.

The components of smart city governance should be structured for participatory decision making processes for the diverse type of actors involved in smart city development, where the actors are represented in an ecosystem (Ooms et al., 2020). Hence, the next section will present relevant ecosystem theory for smart city development.

3.4 Smart cities and ecosystem theory

In this section, we present relevant theory for smart city ecosystems by relying on both innovation ecosystem literature and smart city literature. Ooms et al. (2020) argue that there is a link between smart city development and innovation ecosystems, and states smart cities resembles innovation ecosystems. In a smart city context, the rationale of the innovation ecosystems is to find new solutions to city-specific problems by initiating, importing, modifying and diffusing smart technologies (Dameri et al., 2016). Further, the superior goal is to increase citizens quality of life in a sustainable manner (Ooms et al., 2020). Hence, we first introduce the general aspects of innovation ecosystems as a research stream, as well as describing innovation literature relevant to smart city development in more detail.

3.4.1 The emergence of innovation ecosystems

The traditional model of innovation follows a linear and downstream path of knowledge from science to applied research, and further to application and production. Over the years this linear model is giving way to a non-linear model, in which ”ideas for innovation come from many sources and stages of economic activity, and a growing number of institutions have become involved in the production and diffusion of knowledge” (Russell and Smorodinskaya, 2018, p.113). This change implies that innovation is getting increasingly more interactive, collaborative and complex, involving more disciplines and directions.

To better understand collaboration structures for innovation, Russell and Smorodinskaya (2018) performed an extensive literature review on the subject. Through their analysis, the two authors worked out a definition for collaboration viewing it as ”the most developed form of interactive communication”(Russell and Smorodinskaya, 2018, p.116). In doing so, the authors differentiate collaboration from networking and cooperation. This is because collaboration is seen as an activity of joint value-creation, with higher mutual activity and intentional strategic integration among actors (see figure 3.2).

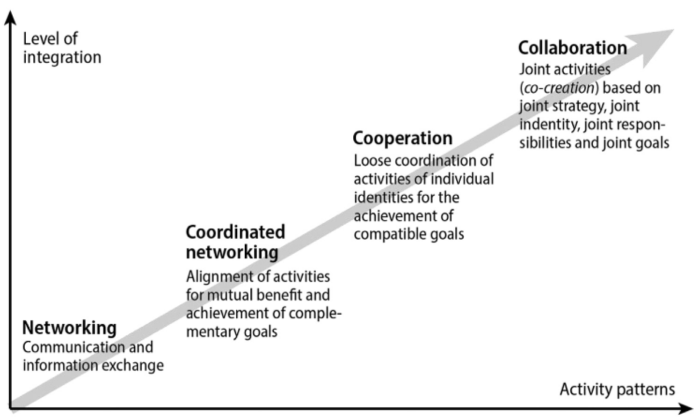

Figure 3.2: The growing complexity of interactions and integration of activities from networking to collaboration (Russell and Smorodinskaya, 2018)

It should be noted that in practice, complex types of relationships may emerge in a non-linear way at varying stages of interactive activities, not necessarily moving in a strict progressive way through all the stages presented in 3.2. Further, literature have shown that there exists many forms of cooperation and collaboration among actors (Russell and Smorodinskaya, 2018). Hence, the following sections will provide a theoretical overview of the various network structures for innovation.

3.4.2 Innovation ecosystems

To understand innovation ecosystems, Russell and Smorodinskaya (2018) uses business networks(BNs) as a basis. BNs describes interactions within the sector/industry and among businesses and other institutional actors. The actors in BNs aim to co-evolve capabilities by working both cooperatively and competitively to the create better products and services (Russell and Smorodinskaya, 2018). The networks are varied and may exists in multiple forms. Thus, they can be open-ended or focused on a concrete project. Further, the literature review findings of Russell and Smorodinskaya (2018) indicate that an ecosystem fosters cross-side beneficiary network effects between all parties, providing the actors with a self-interest in growing the ecosystem further. They found that networks can emerge both from value chain relationships and from accumulation of co-located companies. To provide a picture of how innovation ecosystems fit into the basis of BNs, the authors suggest a framework of three overlapping varieties; cooperation networks, collaborative networks, and triple helix collaborative networks (Fig. 3.3).

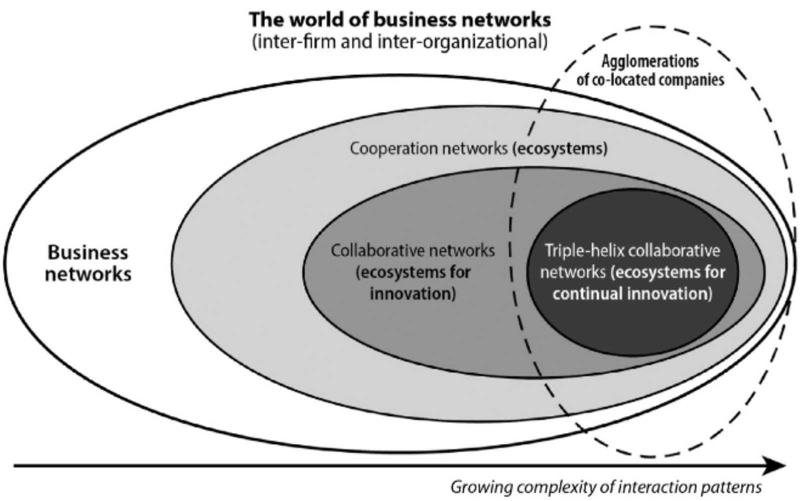

Figure 3.3: Varieties of business networks by different internal interaction complexity (Russell and Smorodinskaya, 2018)

In connection to figure 3.2, cooperation networks can be seen as an ecosystem of interactively linked actors within the same sector that loosely coordinate activities for the achievement of compatible goals. Although, it is worth noting that a cooperation network does not necessary include shared responsibility or joint action. Collaborative networks on the other hand, are an innovation ecosystem of a higher level, enabling not just support of innovation but value co-creation. The networks may be local, national or global and they may have different structures of collaboration. They emerge at the moment when cooperating actors have achieved a certain level of integration concerned with a joint identity, joint strategy and joint goals. The development of innovation ecosystems usually rests on formal and informal communication platforms tailored to enhancing open dialogue and collaborative activities. The last variety of BNs that the authors found was triple-helix collaborative networks.

The triple-helix concept describes networks of actors from at least three institutionally different sectors, representing business sector, academia and public sector. Due to the diversified interactive relationships, these networks can generate a highly sophisticated ecosystem, through which exchange of information and knowledge, as well as co-creation of new knowledge and innovation, can be maximized. Russell and Smorodinskaya (2018) identify triple-helix collaborative networks as ecosystems for continual innovation, and further state that:

> ”A triple-helix pattern of collaboration may increase mutual inter-dependencies within an ecosystem in ways that lead to synergy effects of self-supportive growth, less often observed in less complex ecosystems.” (Russell and Smorodinskaya, 2018, p.118).

Furthermore, the triple helix model was developed by Etzokowitz and Leydesdorff in 1995, embracing the concept of a knowledge economy where actors work together to create economic growth through innovation activities (Cavallini et al., 2016). The interaction among the actors is characterized by each actor having a defined role in the system. The role of the academic institutions is to do research and generate new knowledge. Firms and enterprises produce innovation in form of new organizational structures as well as products and services in the market. Lastly, the governmental bodies have the role of creating new policies and support the technological development (Cavallini et al., 2016).

Since its creation, the triple helix model has been extended and given rise to the quadruple helix model, which includes civil society into the helix. Civil society was added to include the aspect of the citizen needs and their experiences within the system. Adding this dimension ”entailed a shift from technological to social innovation” (Cavallini et al., 2016, p. 15). Meaning that innovation in the public sphere should be driven by the user’s needs. An overview of the actors in the quadruple helix model as well as their roles within the innovation ecosystem is shown in figure 3.4.

A perspective closely related to the helix theory is innovation clusters (Russell and Smorodinskaya, 2018). An innovation cluster is an advancement of classical business clusters which is defined as geographically co-located companies and associated institutions, engaged in a particular field of related industries (Russell and Smorodinskaya, 2018). Innovation

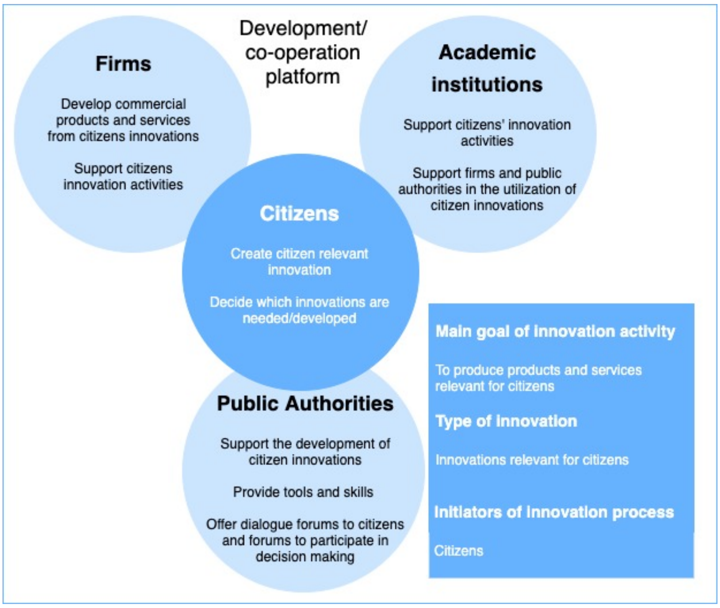

Figure 3.4: The quadruple helix model for innovation. (Carayannis and Rakhmatullin, 2014)

clusters can be considered a special variety of innovation ecosystems, where helix interactions enable unique economic effects of innovation synergy, or continual co-creation of innovative goods and services. Further, the findings of Russell and Smorodinskaya (2018) suggest that ”innovation clusters can develop an ecosystem, or an organizational milieu, in which motives for continual innovation become maintainable, thus leading to a sustainable rise in productivity or ‘competitiveness upgrading’” (Russell and Smorodinskaya, 2018, p.117). The main driver for collaboration in innovation clusters is the implementation of joint business projects. This makes the success of innovation cluster projects directly reliant on the enhancement of collaborative activities (Russell and Smorodinskaya, 2018). Further, innovation clusters consist of co-located actors seeking to develop a unique, smart specialization in ways that enable their community to become geographically localized network nodes of global value chains (Russell and Smorodinskaya, 2018).

3.5 Linking smart city governance and ecosystem theory

Both smart city governance theory and innovation ecosystem theory are important concepts to understand the advancements of smart city development. Innovation ecosystem theory identifies the participating actors in the ecosystem and describes their roles to some extent(Russell and Smorodinskaya, 2018; Carayannis and Campbell, 2009; Cavallini et al., 2016). The smart city governance research complement the ecosystem theory by being able to describe the interests and the power distribution among the participating actors (Gohari et al., 2020), as well as being the driving force for moving the smart city forward (Lee et al., 2014; Ooms et al., 2020). Hence, smart city governance theory has the ability to describe the inter-relations among the participating actors in more detail focusing on the network relationships and the drivers between actors (Lee et al., 2014). By this means, smart city governance functions as the "linking pin" between opportunities for smart city development and the utilization of such opportunities (Ooms et al., 2020; Lee et al., 2014).

It is further important to notice that Ooms et al. (2020) identifies two main differences between the smart city theory and the ecosystem theory. The first difference is related to leadership within the ecosystem. In ecosystem theory, the leadership role is often attributed to an entrepreneur, where the public leaders strongly promotes the importance of the entrepreneur. In smart city literature on the other hand, smart city leadership is often attributed to one or more individuals working for or with public authorities. The second difference between the research streams is the focus on trust and control (Ooms et al., 2020). The ecosystem theory is more focused towards mutual trust, while the smart city literature has enhanced focus on performance measurement (Ooms et al., 2020).

3.6 Inter-municipal collaboration

Compared to larger municipalities, smaller municipalities are characterized with more scarce resources and limited options of actors for collaboration (Hosseini et al., 2018). In this context, inter-municipal collaboration might act as an enabler for smart city development in municipalities with limited ability to take on such projects alone. Yet, there exists limited research on inter-municipal collaboration in the context of smart city development. There are however, some Scandinavian studies that have explored inter-municipal forms of collaboration and the associated benefits (Helin, 2017; Juell-Skielse et al., 2017; Wiberg and Limani, 2015). These studies have identified that the development of inter-municipal collaboration rests on both formal and informal voluntary collaboration structures and communication platforms. Further, it has been found that the aim is to co-evolve capabilities by working both cooperatively and competitively with other municipalities in proximity to create better public services.

The expected benefits of inter-municipal collaboration on digitalization include improved efficiency, effectiveness, service quality, economies of scale of IT investments, information integration and interoperability (Juell-Skielse et al., 2017). In addition, collaboration with external actors might enable the municipality to address issues like lack of adequate professional skills within the municipality and shortage of financial resources (Juell-Skielse et al., 2017; Spicer et al., 2019). Hence, collaboration with external actors is recognized as an alternative way of governing innovation initiatives in order to create value (Juell-Skielse et al., 2017; Helin, 2017; Wiberg and Limani, 2015).

Spicer et al. (2019) is the only article found which describes some characteristics of inter-municipal collaboration in the context of smart city development. According to their findings, rural municipalities tend to partner with large tech firms to be able to facilitate smart city development, ignoring the option of inter-municipal collaboration. However, Spicer et al. (2019) argue that there are several benefits related to partnering with other municipalities instead of large tech firms. These benefits include increased control of smart city processes for local decision-makers, increased ability to store, collect and use data under the terms and conditions of the municipality, and a larger pool of available capital and funding for smart city development. Further, Spicer et al. (2019) argue that inter-municipal collaboration places the technology firms in the position of a vendor rather than a decision maker. Hence, inter-municipal collaboration ensure the municipal ”capacity and scale to build smart cities, without loosing control of the process and outcome”(Spicer et al., 2019, p.17). Even though the paper taps into the benefits of inter-municipal collaboration for smart city development, it does not discuss or formulate any governance models or forms of which inter-municipal collaboration might take.

Regarding informal and formal collaboration structures for inter-municipal collaboration, Wiberg and Limani (2015) analyzes inter-municipal collaboration in general terms. Helin (2017) on the other hand, identify forms of inter-municipal collaboration on digitalization projects. Their study identifies three types of governance models in Finnish municipal ICT ecosystems and finds that the formality of the governance model affects the return on investment, pace of change and continuity of the co-development of ICT services (Helin, 2017). The identified governance models are a voluntary cooperation model, a host municipality governance model and a centralized governance model. A visualisation presentation of these identified collaboration forms is presented figure 3.5, and the forms are further elaborated in the next paragraph.

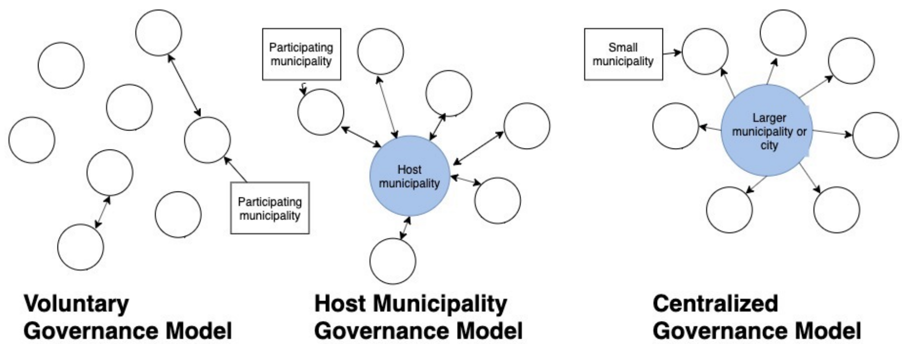

Figure 3.5: Identified governance models of inter-municipal collaboration (The figure is created based on the findings of Helin (2017).)

Similar to the ”Voluntary governance model” of Helin (2017), Wiberg and Limani (2015) has identified an informal structure called ”consultations”. Both describe inter-municipal cooperation as loose structure with no formal political guidance. Cooperation is dependent on personal relationships and they only collaborate if they see a short term benefit. This entails inter-municipal forum for the exchange of information, discussions of experiences, and launch of ideas within a wide range (Wiberg and Limani, 2015). As for more formal governance structures of inter-municipal cooperation, both Helin (2017) and Wiberg and Limani (2015) present two structures. The ”host municipality governance model” and ”centralized governance model” of Helin (2017), somewhat corresponds to forms of ”coordination” and ”contracts” identified by Wiberg and Limani (2015). These formal inter-municipal collaboration structures regard the coordination and contractual activities in the procurement of various municipal goods and services. A characteristic of these formal inter-municipal cooperation forms is that there is a manager (often from the largest collaborating municipality in the network) coordinating the initiatives with a steering group. Overall, both authors have found that inter-municipal collaboration allows for cheaper processes, more effective resource allocation and creation of standards that guarantee interoperability among public agencies. This in turn is expected to lead to better smart city coordination, ICT services and return on investment (Helin, 2017; Wiberg and Limani, 2015)

Chapter 4

IoT in smart city development

The Internet of Things (IoT) is an enabling technology for smart municipalities and smart cities, and is one of the main technologies deployed (Wirtz et al., 2019; Telenor, 2019c). IoT refers to the inter-connection and exchange of data among devices/sensors. It further includes the ability to aggregate, merge, analyze and process the collected data to obtain actionable information. The goal is to provide intelligent and complicated services in a multitude of areas, enabling integration of variety of end systems transparently and seamlessly (Mekki et al., 2019; Abualese et al., 2019; Telenor, 2019b).

In this chapter we first present theory related to IoT as smart city enablers in municipalities, and identify areas of application for IoT. Next, an brief overview of the IoT value chain is presented as well as an introduction to different IoT connectivity alternatives and 5G technology.

4.1 Application areas for IoT

The potential applications for IoT is vast, ranging from smart consumer wearable with sensors to smart grid management in power utilization. Further, IoT can make municipalities smarter by by real-time monitoring of municipal services and increase citizen participation by collecting citizen data (Guenduez et al., 2020). Further, IoT devices can be deployed in a multitude of municipal services such as health care, waste management, pollution control, drinking water monitoring, reduction of traffic congestion and winter road maintenance (Mehmood et al., 2017; Abualese et al., 2019; Velsberg, 2019). This is done by implementing sensors in houses, vehicles, streets, buildings and many other public environments (Díaz-Díaz et al., 2017; Wirtz et al., 2019). Thus, IoT is an enabling technology for smart municipalities, and is one of the main technologies deployed (Díaz-Díaz et al., 2017; Wirtz et al., 2019).

Figure 4.1 presents examples of IoT application areas for different industries and users.

It shows that IoT has a broad set of application areas and that sensors can aid in the process of optimisation, automation and control.

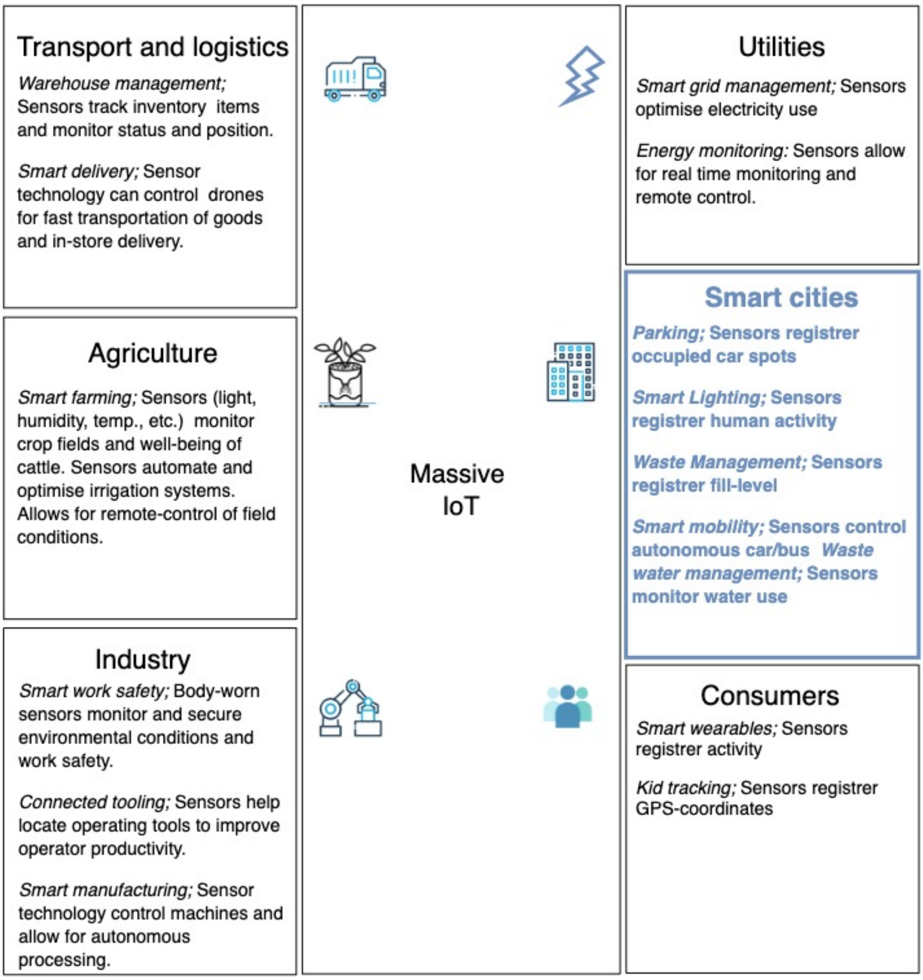

Figure 4.1: Examples of IoT application areas, inspired by Ericsson (2020b)

4.1.1 IoT as a smart city enabler in the municipality

Pfister et al. (2019) state that the base currency of smart cities is data, and the importance of data sharing and data-driven decisions in the municipalities is reflected in the digitalization-strategies of the Nordic countries (KMD - Norwegian Ministry of Local Government and Modernisation, 2019; Swedish Association of Local Authorities and Regions (SKR), 2019; Local Government Denmark, 2019). By equipping the municipality with IoT devices, the local government becomes able to monitor almost every aspect of the municipality, and take immediate action when problems occur, as well as provide the citizens with relevant information and services (Velsberg, 2019). However, towns and municipalities can only be smart if they have intelligent tools and structures in place to integrate and synthesise data for a specific purpose (Pfister et al., 2019). The pressing issue in this context is how the municipalities can adapt their traditional structures and processes to create value from IoT-solutions (Wirtz et al., 2019). Hence, IoT has gained significant importance in science and management research towards a smarter public sector (Wirtz et al., 2019).

In addition, both management aspects and technological requirements need to be considered when IoT is implemented in municipal services. In terms of management aspects, utilization of IoT require organizational change, new public business models and decision support systems in the municipality (Wirtz et al., 2019). Further, the IoT system needs to be synthesized and integrated with public services, and the deployment of IoT systems need to be carefully planned in order to anticipate and avoid potential difficulties (Velsberg, 2019).

In terms of technological requirements of the IoT system in municipal services, the decision-makers need to know the amount of data the system should generate, and if the service require real-time connections (Velsberg, 2019). Further, requirements for quality of service, as well as security and privacy are important topics which must be discussed before implementation (Ten Berg et al., 2019; Lee, 2019; Abualese et al., 2019). Additionally, decision-makers need to consider the IoT systems ability to integrate several data sources and types of technologies (Ahlgren et al., 2016; Raghavan et al., 2020; Markendahl et al., 2017; Lee, 2019). Open systems are also important in order for the data to be openly shared across municipal departments and functions (Guenduez et al., 2020).

4.2 An overview of the IoT value chain

The IoT value chain consists of three layers, where each consecutive layer is dependent on the previous one. Figure 4.2 provides an overview of the IoT value chain as a whole. The first part, the IoT layer, consist of the IoT devices and sensors as well as the network technology (e.g LPWAN), ensuring transmission of data from source to destination (Abualese et al., 2019; Telenor, 2019b). The different IoT connectivity alternatives in the IoT layer are presented in section 4.3.

The next layer of the value chain, the IoT platform layer, integrates data from several data sources and processes the data using in example machine learning algorithms. Important components of an IoT platform is cloud computing and cloud storage which has the ability to store, process and manage massive amounts of data, as well as enable data sharing and distribution (Abualese et al., 2019; Telenor, 2019b).

Lastly, the access layer of the value chain represents the applications used by the end-customers. The application make use of, and visualizes the data in order to provide the customer with insight and thereby create customer value (Telenor, 2019b).

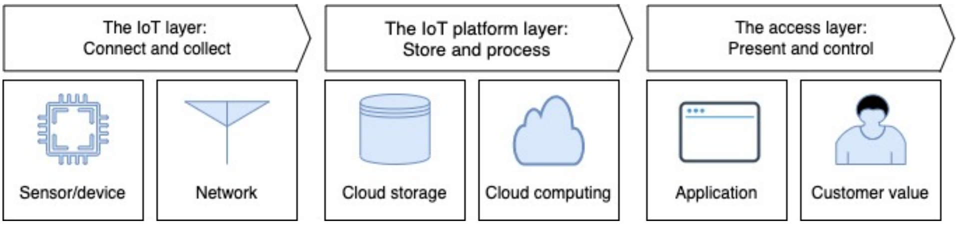

Figure 4.2: An overview of the IoT value chain. Inspired by Telenor (2019b)

4.3 IoT connectivity alternatives

The term massive IoT has been introduced to describe IoT-devices which are low-cost and low-energy consuming, but are less latency sensitive and has lower throughput requirements (Ericsson, 2020b). A new type of network technology, called Low Power Wireless Area Network (LPWAN), has been designed to meet the connectivity requirements of massive IoT. Previously, IoT-devices have been communicating over mobile networks with high data rate and fast throughput, designed to meet consumer needs. LPWAN on the other hand, is designed for low cost, low data rates and long battery lives to operate in locations that is often hard to reach (Telenor, 2020). The battery life of the devices is increased by reducing the radio communication between device and LPWAN network. The energy consumption is reduced by letting the devices go into sleep mode and less often listen to the network (Telenor, 2020).

The connectivity alternatives for transmitting data from IoT-devices can be grouped into two main alternatives with different characteristics: Unlicensed LPWAN-technologies and cellular technologies (Ericsson, 2020a). Examples of the first is LoRaWAN and Sigfox, while examples of the latter is NB-IoT and LTE-M (Ericsson, 2020a; Mekki et al., 2019). Table 4.1 provides an overview of the characteristics of the different network types.

There are several advantages of the cellular network protocols NB-IoT and LTE-M. They have higher bandwidth capacity, quality of service (QoS) and higher level of security. They are considered to be 'secure by design', in contrast to protocols operating in the unlicensed spectrum (GSMA, 2019c), and they can be deployed on top of the existing 4G network as well as being forward compatible with the 5G network (Telenor, 2020). In addition, telecommunication operators provide end-to-end IoT platforms on top of the cellular networks that allow customers to scale and manage their business requirements, as well as technical and business support to react to the customer's changing needs (GSMA, 2020). However, NB-IoT and LTE-M meet the demands of different use cases (Telenor, 2020). The LTE-M protocol has higher bandwidth capacity than the NB-IoT network, and is thereby the best cellular option for moving devices and voice applications (Telenor, 2020; Sierra Wireless, 2017). NB-IoT on the other hand, is more suitable for transmitting data from static devices (Telenor, 2020).

Ballerini et al. (2020) points out LoRAWAN and NB-IoT as the driving protocols for the

Table 4.1: Overview of todays leading LPWAN-technologies. (Mekki et al., 2019; GSMA, 2020)

Characteristics	Unlicensed LPWAN		Cellular technologies		Source
	SigFox	*LoRa/LoRaWan*	*NB-IoT*	*LTE-M*	
Year Launched	2010	2009/2015	2016	2016	(Mekki et al., 2019) (GSMA, 2020)
Standardization	ETSI*	LoRa-Alliance	3GPP	3GPP	(Mekki et al., 2019) (GSMA, 2020)
QoS	Low	Low	High	High	(Mekki et al., 2019)
Maximum bandwidth	50 kbps	0.6kbps	260 kbps	1Mbps	(Bearingpoint, 2020) (Telenor, 2020)
Maximum battery lifetime	Up to 10 years	Up to 10 years	Up to 10 years	Up to 10 years	(Bearingpoint, 2020)
Coverage	Depends on the number and location of gateways	Depends on the number and location of gateways	National scale in areas with infrastructure	National scale in areas with infrastructure	(Ballerini et al., 2020) (GSMA, 2020)

IoT-ecosystem, and has therefore compared the two. In order to have a fair comparison, the two technologies were compared under the same conditions. Based on the comparison of the two standards, the paper provides guidelines for the choice of technology under different circumstances. However, the paper recognizes that NB-IoT, when deployed nationally, has the advantages of shorter time to market with plug-and-play solutions, while LoRaWAN require that the customer to builds and maintains their own infrastructure (Ballerini et al., 2020).

4.4 Massive IoT and 5G

The 5G network increases the potential of massive IoT by making several new use cases possible (Telenor, 2019a). It is the technological characteristics of 5G that act as enablers for new use cases. The technological characteristics of 5G are network slicing, more robustness and quality, lower latency, higher throughput and the possibility to connect a massive number of devices with a wide range of speed, bandwidth and QoS requirements (Telenor, 2019a; GSMA, 2019b).

Network slicing refers to logical or virtual networks added on top of the 5G-infrastructure. The practical implications of network slicing is its flexibility to fit network characteristics such as bandwidth, throughput and latency to each use case. Some use cases, such as waste management, only require sensors to transmit small amounts of data, but requires networks with low energy consumption. Other use cases, such as emergency services, are dependent on low latency, high throughput and secure transmission. The advantage of the 5G network is its ability to handle both use cases by using network slicing (Telenor, 2019a). Further, the 5G network is able to handle a massive number of connected devices and sensors. To fully exploit the potential of massive IoT, the network needs to be able to handle millions of devices per square kilometres. 5G technology stand out as the network able to handle such a huge number of devices (Telenor, 2019a).

Critical communication is an area where 5G introduces new use cases for IoT(Telenor, 2020). In example, 5G enable emergency services to use sensors and transmit data as the technology meets the service's need for low latency, a secure network, few errors and extremely high QoS. Further low latency, security and QoS are a preconditions for autonomous cars and increased use of sensors within the health sector (Telenor, 2019a).

Chapter 5

Digitalization of Nordic municipalities

This chapter describes contextual factors that might influence the state of smart city development in Danish, Finish, Norwegian and Swedish municipalities. First, this chapter provide the thesis' definition of medium-sized municipalities and discuss alternative definitions used by the Nordic countries. Next, general urbanization and population growth aspects of the Nordic countries are described. Further, a short description of the local autonomy of Nordic municipalities is presented. Lastly, national and regional influences on digitalization in the Nordic municipalities are presented, as well as an overview of the deployment of LPWAN-networks in the Nordic region. Lastly, one section is dedicated to each country to further describe their characteristics.

5.1 Defining municipal size

Relative municipal sizes is not a uniform term across country borders, and many academic articles refer to municipal size without defining it properly. However, as outlined in this section, size can be used to differentiate the demographic, geographic, social and economic conditions of municipalities and their service provision.

The fundamental metrics for defining municipal is area and population size. Additional geographic and demographic metrics are expected population growth, sparsity of the population (inhabitants $/km^2$), the geographical position, and the number urban areas in the municipality. An urban area can be defined in terms of form, size and function (Nordregio, 2019a). A common approach to define urban areas is to "focus on the number of people living together within a defined area considered to have urban physical characteristics" (Nordregio, 2019a, p.39). Further, there is a difference between urban settlements [1] and

[1] In the Nordic region an urban settlement is considered to be 200 people living within 200 meters (in Norway 50 meters).

functional urban areas [2], where a functional urban area might consist of multiple urban settlements. A municipality can have multiple urban settlements or one functional urban area that cross multiple municipal borders (Nordregio, 2019a).

In terms of defining municipal size, there is no coherent definition among the Nordic municipalities. Each country have their own, complex definition of size. An overview of the size definitions of each country is given in appendix A. All the countries uses different metrics to classify their municipalities in size categories. However, all countries use some variation of municipal population size as a metric, either the total number of inhabitants or the number of inhabitants in biggest or smallest urban settlement. Further, Norway categorizes based on bound costs and municipal disposable income (Statistics Norway, 2018), while Sweden categorize on commuting patterns (Statistics Sweden, 2017), Finland on % of population living in urban settlements (Statistics Finland, 2019), and Denmark on the number of workplaces within the municipality (Statistics Denamrk, 2018).

Hence, due to the complexity and variety of municipal size definitions, the size criteria for medium-sized case municipalities in this thesis is defined to be population size of 20.000 - 60.000 inhabitants. The size interval is set to include case-municipalities which are large enough to have initiated their own smart city projects, but small enough to have different demographic, social and economic characteristics than larger cities. Further, most smart city literature is focused towards large and mega cities, where the cities represented in smart city rankings have almost always more than 100.000 inhabitants (The IMD World Competitiveness Center, 2019; Eden Strategy Institute, 2018; Giffinger et al., 2007; European Comission, 2016).

5.2 Urbanization and population growth

The Nordic region is characterized as sparsely populated, and with fewer mega cities compared to the rest of Europe. In 2018 around 75% of the European population lived in urban areas, and it is expected that this will increase to almost 85% in 2050 (United Nations - Department of Economic and Social Affairs, 2019). In comparison, only 45% of Nordic residents lived in functional urban areas in 2016, indicating that more Nordic residents live in less densely populated areas compared to the rest of Europe (Nordregio, 2019a). This especially true for Norway and Finland, while Denmark is more densely populated. Meaning that Denmark has more proximity between functional urban areas compared to the rest of the Nordic countries.

Further, the population growth rate varies strongly across the Nordic municipalities, with the largest cities and their surroundings having the highest population growth rates. The Nordic countries experience similar trends as the rest of the world, urban areas are experiencing a higher population growth rate than rural areas. Especially inland rural municipalities in Norway and Sweden experience population decline. On the other hand, areas around Oslo, Stockholm, Copenhagen and Helsinki had the most intense population

[2] A functional urban area is defined by OECD as an area with a population size above 50.000 and 1.500 inhabitants $/km^2$.

growth in the period 2011-2016 (Nordregio, 2019a). This includes municipalities situated within the functional urban areas that surround the largest cities. Urban areas in Sweden and Norway have experienced the strongest population growth rate in the Nordic region with a population growth rate around 10% (Nordregio, 2019a).

Population growth and urbanization requires cities and municipalities to streamline and create better digital services in order to meet the citizen's needs. However, all urban areas are not the same. In the Nordic countries, small and medium-sized cities and municipalities face explicit and often rather different challenges in terms of social, economic and environmental sustainability compared to larger cities and central regions (Nordregio, 2019a).

Further, the Nordic countries' urban qualities in small and medium-sized cities have been prioritised as important areas of regional development (Nordregio, 2019a). Even though people are moving to more urbanized areas, it is not evident that urbanization is reserved to the largest cities. Small and medium-sized municipalities have the potential to remain attractive places to live through development programs and municipal service improvement. Digitalizing to create better and more seamless services might prove an important step for small and medium-sized municipalities to increase their attractivity.

5.3 Local Autonomy

The Nordic countries are characterised with regions and municipalities with high degree of local autonomy. Compared to other European countries, the Nordic countries distinguish themselves with a wide range of tasks and great organizational freedom. Local authorities in the Nordic countries have the freedom to organize themselves after local needs. Additionally, a large share of the municipal income is from local funding (Baldersheim et al., 2019). The degree of local autonomy is a foundation for local government effectiveness and defines the space for local democracy to unfold.

Overall, Finland is considered to have the highest degree of local autonomy among the Nordic countries (Baldersheim et al., 2019). However, when it comes to interactive governance, which is the local authorities opportunity to influence national policy-making, Norwegian municipalities have the strongest position. In Denmark and Sweden on the other hand, the local government is considered to be a corrective force for national policy-making, meaning that the local government is first and foremost a source of learning and correction (Baldersheim et al., 2019). In these two countries, the degree of interactive governance is somewhat lower than for Finland and Norway.

Compared to the other Nordic countries, the Norwegian municipalities have lower fiscal autonomy due to stronger national regulations on taxation (Baldersheim et al., 2019). According to (Baldersheim et al., 2019), Norway has the most limited scope of local democracy of the Nordic countries both when it comes to financial autonomy, the freedom of the municipality to control financial resources, and functional autonomy, the ability to control the objectives and the goals of the local government. However, Norway has the highest scores in interactive governance, meaning that local government has a strong position when it comes to national policy-making that affects the municipalities (Baldersheim et al., 2019).

5.4 National and regional influences on digitalization

The Nordic countries are above the EU average in several digitalization indexes (United Nations, 2018; European Commision, 2019; inCITIES Consulting, 2020), and are considered digital front-runners in both the European and global context (Nordregio, 2019b). All the Nordic countries are in the process of implementing national digitalization strategies where digital technologies are viewed as tools to realize local and national goals and focus on digitalization at a local level by responding to local challenges, needs and priorities (Nordregio, 2019b). Hence, the digitalization processes in Nordic municipalities can provide insight on how public services should be further developed. However, there are some significant differences in how the countries govern digitalization efforts on a national level (Von Marion and Hovland, 2015).

There are several national organizations that influences the direction and focus of digitalization within the municipalities. First, each of the Nordic countries have a municipal association with the core task of advocating the interests and development of municipalities and their partner organizations. The national association of each country are The Local Government (KL) in Denmark, the Association of Finnish municipalities (Kommunförbundet), in Finland, the Norwegian Association of Local and Regional Authorities (KS) in Norway, and the Swedish Association of Local Authorities and Regions (SKR) in Sweden (KL, 2020; SKR, 2020; KS, 2020; Kommunförbundet, 2020).

In addition to the municipal organizations, all the Nordic countries have national agencies that advocate the direction of digitalization at a national level. In Denmark, Norway and Sweden, this position is held by a dedicated national agency for digitalization. In Denmark this is the Danish Agency for Digitalization, in Norway the organization is Difi, and in Sweden this position is held by eSam (Von Marion and Hovland, 2015). In Finland, on the other hand, it is the ministry of Finance that is considered as the core policy provider for ICT and digitalization. However, Finland do have a government agency at an operational level. the organization Valtori deliver sector-independent ICT services for the central government. The services delivered is a combination of the organizations own service production and commercial services provided by trusted partners (Valtori, 2020).

Yet, there are some differences between these national digitalization agencies in the governance tools available. In Denmark, the Danish Agency for Digitalization has direct access to decision-making processes in municipalities, regions and state sectors through a budget negotiation role. While in Norway, Difi, is not directly involved but defines regulations and standards (Von Marion and Hovland, 2015).

5.5 LPWAN-deployment in the Nordic region

As described in section , IoT systems are dependent on long range, low energy consumption and cost effectiveness, rather than high data rates and fast throughput. Hence, the roll-out of commercial networks designed to meet these requirements is of interest. An overview of the current operators providing commercial networks for IoT in the Nordic region is given in table 5.1.

Table 5.1: Nationwide NB-IoT and LTE-M deployment in the Nordic countries. (GSMA, 2019a)

Country	Operator	LTE-M	NB-IoT	LoRa	Sigfox
Denmark	*Telenor*				
	Telia				
	TDC				
	*Sigfox**				
	*LoRa-Alliance**				
Finland	*DNA*				
	Elisa				
	Telia				
	*Sigfox**				
	*LoRa-Alliance**				
Norway	*Telenor*				
	Telia				
	*LoRa-Alliance**				
Sweden	*Telia*				
	*Sigfox**				
	*LoRa-Alliance**				

In terms of IoT-networks operating on licensed frequency bands, commercial NB-IoT networks has been deployed in all of the Nordic countries, while the LTE-M network has been deployed in Denmark, Finland and Norway (GSMA, 2019a). In terms of deployment of networks operating on unlicensed frequency bands, multiple companies have deployed LoRa-networks in all of the Nordic countries (LoRa - Alliance, 2019). However, it is important to note that this does not mean nationwide coverage of the network, but rather that the network has been deployed locally in some municipalities in the Nordic region. Sigfox on the other hand, has full coverage in Denmark, the southern part of Finland and central regions in the southern part of Sweden. Sigfox is not deployed in Norway (Sigfox, 2019).

5.6 Country characteristics

5.6.1 Denmark

Denmark has 99 municipalities and 5 counties (Statistics Denamrk, 2018). There are 65 municipalities which are considered to be of medium size, and they hold 48 % of the total population. An overview of the population distribution among small, medium and large municipalities in Denmark is given in table 5.2.

Table 5.2: The total population distribution on municipal size in Denmark (Statistics Denmark, 2020).

Size	Interval	# of municipalities	Population	% of total population
Small	0 - 20.000	9	78319	1%
Medium	20.000 - 60.000	65	2591055	48%
Large	60.000-	25	3153389	59%

The Danish municipal organization (KL) identifies digitalization as an important area in local politics. They argue that digitalization is important to the municipalities, because technology and citizens meet at the local level. The strategy document ”På forkant med fremtidens velfærd - strategi for digitalisering, data og teknologi” (At the forefront of future technology - strategy for digitalization, data and new technology), replaces the 2016 - 2020 digitalization strategy for Danish municipalities. The new strategy argue that it is now time to change course. The focus in the municipalities should be that of identifying the new technology that is the best fit for local needs instead of building large digital systems. Additionally, KL wants to create a debate on how to develop inter-municipal solutions and how municipalities should collaborate (Local Government Denmark, 2019). Further, the role of KL in the development of digital services is to identify the most mature technologies which has the most potential. Their role is also to ensure that all municipalities are part of the digital development, and facilitate that some municipalities take the lead and experiment with new solutions, while other municipalities transfer the solutions these front-runners (Local Government Denmark, 2019).

Further, the new KL strategy outlines a set of elements that are important to the new direction of digitalization. First, the municipalities need to identify the most promising technologies for their needs. Second, the municipalities should make use of existing development resources in the market and build upon existing solutions. Third, digital service solutions should be common and standardized and available for all municipalities. Fourth, the municipalities should focus on opening and sharing data and ensure that digital transformation increase the quality of the core welfare. Last, the new strategy has an increased focus on security and citizen trust as well as developing stronger municipal science labs for digitalization.

5.6.2 Finland

Finland has 310 municipalities and 19 counties. There are 39 municipalities which are considered to be of medium-size, and they hold 23 % of the total population. An overview of the population distribution among small, medium and large municipalities in Finland is given in table 5.3.

The governance structure in Finland differs from the governance structures in Denmark,

Table 5.3: The total population distribution on municipal size in Finland (Statistics Finland, 2020).

Size	Interval	# of municipalities	Population	% of total population
Small	0 - 20.000	254	1499782	27%
Medium	20.000 - 60.000	39	1252450	23%
Large	60.000-	17	2773060	50%

Norway and Sweden which is considered to be more similar. While the other Nordic countries have one national agency which is dedicated to steering digitalization across public organizations, there are several organizations that aspire to define the strategic direction of public digitalization in Finland (Von Marion and Hovland, 2015). As mentioned it is the ministry of Finance that is considered to be the core policy provider for ICT and digitalization. However, it is the Finnish Ministry of Transportation and Communication that has developed the most recent digital infrastructure strategy. The strategy sets goals towards 2025 and focuses on how Finland should continue to build their digital infrastructure by improving wireless and fixed broadband. The objective of the strategy is to achieve a situation where the digital infrastructure supports automation, robotization, real-time data economy, which will promote the next stages of healthcare, media education and transport (Finish Ministry of Transport and Communications, 2019).

5.6.3 Norway

Norway has 356 municipalities and 11 counties. Of these, 48 municipalities is of medium size, and they hold 29% of the total population. An overview of the population distribution among the small, medium and large municipalities is given in table 5.4.

Table 5.4: The population distribution on municipal size in Norway (Statistics Norway, 2020)

Size	Interval	# municipalities	Population	% of total population
Small	0 - 20.000	294	1596412	30%
Medium	20.000 - 60.000	48	1554916	29%
Large	60.000-	14	2216252	41%

In Norway, the Norwegian Association of Local and Regional Authorities (KS) has formed the public digitalization strategy together with the national government. The strategy is called One Digital Public Sector and outlines the public digital strategy from 2019 to 2025. The main goal of the strategy is for the citizen to experience streamlined digital public services. The main goal of the strategy is to create a simpler everyday life for citizens and businesses, with focus areas such as seamless services, coordination across administrative levels and sectors, data sharing, common national solutions in an ecosystem and cooperation with the private sector (KMD, 2019b). Governing digitalization projects in Norway is considered decentralized and sectorial where the municipalities have the responsibility of their own digitalization projects. There is a low degree in centralized steering of digitalization (Struensee Co, 2017).

5.6.4 Sweden

Sweden has a total of 290 municipalities and 25 counties. According to our definition of municipal size, there are 85 municipalities considered to be medium. This is 29% of the total population. An overview of the population distribution among small, medium and large municipalities in Sweden is given in table 5.5.

Table 5.5: The total population distribution on municipal size in Sweden (Statistics Sweden, 2020).

Size	Interval	# of municipalities	Population	% of total population
Small	0 - 20.000	167	1814070	18%
Medium	20.000 - 60.000	85	2966274	29%
Large	60.000-	38	5474758	53%

SKR has developed a strategy to establish the fundamental prerequisites for developing digital services in Swedish municipalities. It states that the major part of developing new digital services takes place in the Swedish municipalities and regions. However, it is the role of the national government, as well as SKR, to reduce barriers and facilitate the digital development in Swedish municipalities and regions. SKR outlines an overall goal and a set of four sub-goals for the digitalization processes. The overall goal is related to creating more effective and innovative municipal services to reach municipal goals and visions. The first sub-goal is to ensure leadership, governing and the organisation's readiness for innovation and digital service development. The second sub-goal is a common framework and standards for architecture and security. The third sub-goal is open data sources and a digital infrastructure. And the last sub-goal is digital service development after citizen needs. The strategy also outlines the roles and responsibilities of SKR, as well as the municipalities. In general SKR and the national government have the role as facilitators. The municipalities are responsible for identifying citizen needs and establish requirements for digital services, as well as using procurement as a strategic tool for increased standardization and bringing up local innovations to a national level (SKR, 2019).

Chapter 6

Smart city development in Nordic medium-sized municipalities

Smart city development in Nordic medium-sized municipalities

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Abstract
The Nordic countries stand out as digital front-runners in Europe as well as in a global perspective. However, smart city development in medium-sized municipalities in the Nordic region is less researched than large Nordic cities. Hence, the purpose of this paper is to study how medium-sized municipalities in the Nordic region are organized for smart city development, and how the development is influenced by contextual factors. Data has been collected through interviews of smart city and digitalization leaders in medium-sized municipalities in Denmark, Finland, Norway and Sweden, as well as secondary data in the form of strategy documents, statistics and reports. The analytical approach is multiple case study analysis where the selected case-municipalities are analyzed and compared in terms of understanding of the smart city concept, smart city governance, resources and collaboration. Our findings indicate that there are great variations in the maturity of smart city development in medium-sized municipalities in the Nordic region. The findings indicate that successful implementation of smart city projects is related to a structured organizational setup, clear goals and strategies, support from a strategic facilitator and focus on project scaling. Further, the findings suggest that the contextual factors local autonomy, local conditions and the country-level approach to public innovation influence smart city development. The paper provides originality and value by identifying characteristics on how smart city development is organized in medium-sized municipalities across Nordic countries, and how the development is influenced by contextual factors.

Keywords: Smart city development, Smart city governance, Contextual factors, Municipality, Nordic Region

1 Introduction

The Nordic countries, Denmark, Finland, Norway and Sweden stand out as digital front-runners in Europe, and are in the top-tier of many digitalization indexes [European Commision, 2019a, inCITIES Consulting, 2020a, United Nations, 2018]. Several factors indicate that the Nordic countries have great potential for integrating smart technologies both to create value for citizens and in a commercial context. Smart technologies refers to technologies used to generate value from data and includes amongst other; internet of things, 5G and cloud computing [Lemke et al., 2020]. In terms of progress towards a digital economy and society, the Nordic countries are above the EU average when it comes to mobile and fixed network deployment, degree of human capital (ICT experts and internet user skills), online activities and transactions, integration of digital technology and use of digital public services [European Commision, 2019a]. Additionally, the Nordic countries have a strong position when it comes to 5G readiness. The countries are considered to have the infrastructure and technology, the regulation and policies, innovative landscape and human capital needed for adaption of 5G technology [inCITIES Consulting, 2020a].

Further, large cities in the Nordic countries are often represented in the top-tier of smart city rankings. All the Nordic capitals are amongst the top 50 smartest cities in the world [The IMD

World Competitiveness Center, 2019, Eden Strategy Institute, 2018]. In addition to the capitals, several large Nordic cities have been represented in the top rankings of European smart cities [Giffinger et al., 2007, European Comission, 2016]. Hence, Nordic cities stand out as able to integrate smart technologies in public services.

However, the Nordic countries are also characterized with more scattered settlements, and smaller cities compared to the rest of Europe. 75% of Nordic residents live in urban settlements[1] with more than 2.000 inhabitants. However, only 45% lives in urban areas with more than 50.000 inhabitants[2] [Nordregio, 2019a]. Hence, small and medium-sized communities and cities have a strong position and are prioritized in regional development in the Nordic countries. The Nordic countries do experience depopulation in rural areas, but small and medium-sized municipalities have the potential to remain attractive places to live through development programs and municipal service improvement. Digitalizing to create better and more seamless services might prove an important step for small and medium-sized municipalities to increase their attractiveness [Nordregio, 2019a].

Even though the Nordic countries stand out as digital front-runners at a country level, few studies have examined the smart city development in medium-sized municipalities in the Nordic countries. Existing research on smart city development in the Nordic countries includes a framework to evaluate and adjust smart city metrics to arctic and remote locations [Raspotnik and Herrmann, 2020], and an article on governance structures of smart city initiatives in three medium to large sized cities in Norway [Gohari et al., 2020]. However, research within the area remains scattered, and there are no studies to our knowledge which comprehensively study smart city development in medium-sized Nordic municipalities.

In order to fill this gap of research, we perform a multiple case study analysis of one Norwegian, Swedish, Finnish and Danish municipality and proposes the following research question:

How is smart city development organized in medium-sized municipalities in the Nordic region?

The research question aims to create an understanding of the state of smart city development in the selected Nordic municipalities. It is further interesting to discuss how contextual factors such as local autonomy and local conditions affect smart city development. Additionally, there are significant differences in how the countries govern digitalization efforts on a national level [Von Marion and Hovland, 2015] which might also have influencing effects.

In order to perform the multiple case study analysis, we use a framework consisting of four dimensions with related sub-dimensions. The dimensions are the understanding of the smart city concept, smart city governance, smart city resources and smart city collaboration. The framework was created to be able to organize and compare the empirical data from the four cases, and was established by considering the applicability of existing theoretical frameworks to the empirical data.

The rest of this paper is structured as follows; in section 2 relevant research regarding smart city development is described, next the Nordic context is described in section 3 to understand the country-level dynamics which might have an effect on smart city development. Further section 4 presents the methodology which includes the case selection criteria, a description of the data and how it has been collected, and a presentation of the analytical framework used to analyze the data. In section 4.4, short descriptions of each of the cases are given. The main part of the article is section 5 which presents the findings from the case-municipalities in a systematic way. Last, section 6 discuss the findings of the analysis and points out limitations and areas of further research.

[1] In the Nordic region an urban settlement is considered to be 200 people living within 200 meters (in Norway 50 meters).

[2] A functional urban area is defined by OECD as an area with a population size above 50.000 and 1.500 inhabitants $/km^2$.

2 Theoretical Background

This section presents the relevant theory related to digitalization and smart city development in medium-sized municipalities. The two concepts are strongly related, however, they are not strictly defined terms, thus, they can be understood and analyzed from multiple perspectives. First, the smart city concept is placed in the context of the advancements of an e-government to a smart government, conceptualized in the e-government stage model [Layne and Lee, 2001, Lee et al., 2014]. Further, the relation between a smart government and a smart city is explained [Anthopoulos and Reddick, 2016], and the smart city concept is elaborated [Mora et al., 2019, Appio et al., 2019, Bedford et al., 2011]. Next, applicability of the smart city concept is discussed in relation to municipal size and territorial and demographic factors [Chen and Kim, 2019, Raspotnik and Herrmann, 2020, Giffinger et al., 2007, Hosseini et al., 2018, Spicer et al., 2019, Desdemoustier et al., 2019, Borsekova et al., 2018]. Last, relevant theory related to the governing of smart city development is presented [Argento et al., 2019, Ooms et al., 2020, Gohari et al., 2020] and the related smart city ecosystem [Carayannis and Campbell, 2009, Dameri, 2014, Ardito et al., 2019, Cavallini et al., 2016].

2.1 From e-government to smart government and smart cities

The e-government concept describes how information and communication technologies (ICT) are being used to support public duties efficiently and effectively [Wirtz and Daiser, 2015]. Further, the e-government stage model describes the level of which a government has been able to use information and communication technologies to integrate and improve their services [Layne and Lee, 2001]. The stages includes publishing information, interaction and transaction, vertical integration and horizontal integration sharing information with other agencies [Layne and Lee, 2001].

The first step, publishing information, is the most basic form of e-government and describes to what extent the municipality provides information to its citizens online. Interaction and transaction takes it one step further and includes digital user interaction with citizens, in example online registration or payment of services [Chen and Kim, 2019]. Taking the step from a transactional e-government to the integrated stages (stage three and four), requires organizational change. The third stage includes linking local systems to higher level systems within similar functionalities [Layne and Lee, 2001]. In the fourth stage, horizontal integration, systems are integrated across different functions which enables information obtained by one agency to propagate through all government functions [Layne and Lee, 2001]. The forth stage also includes open government data, digital complaint management, collaborative project systems and electronic consultation of public stakeholders [Wirtz and Daiser, 2015]. The stage model has later been expanded to include a fifth stage focusing on the transition from an e-government to a smart government. Governments in this fifth stage are data driven and able to proactively use and deliver information to citizens. Services of smart governments are designed to support automation and intelligent processing of available information [Lemke et al., 2020]. A smart government uses Big Data Management, the Internet of Things (IoT), sensor networks, smart devices, embedded systems, 5G and cloud computing technologies in public administration to create entirely new ways of governing cities, states or nations [Lemke et al., 2020].

The smart government concept is also strongly related to smart cities, and some scholars view smart city as a subset of the broader concept smart government. A smart government is able to do smart city development, where smart city is an area for collaboration and service co-production testing [Anthopoulos and Reddick, 2016].

The ambition of a smart city is to increase the competitiveness of local communities through innovation, and at the same time increase quality of life for its citizens through better public services and a cleaner environment [Appio et al., 2019]. Smart city initiatives can be classified according to six dimensions, namely quality of life (Smart Living), competitiveness (Smart Economy), social human capital (Smart People), public and social services and citizen participation (Smart Governance), transport and communication infrastructure (Smart Mobility), and natural resources (Smart Environment) [Giffinger et al., 2007]. It can also be viewed as a five level pyramid [Bedford et al., 2011]. The foundation of the pyramid are the basic requirements that have to be present in order to create a smart city, namely the physical areas of the city (e.g. buildings, parks and public spaces) and and the infrastructure (e.g. network deployment, transit roads, energy and water) needed to make the city smart. The top three levels includes collaborative ecosystems, applications (e.g e-government) and living. Further, smart city strategies can be viewed as either "hard" or "soft". The hard smart city strategies focuses on infrastructure and technology, while the soft strategies focuses on developing human and social capital [Angelidou, 2014]. Hence, the scope of smart city development is broad and can be implemented to improve a multitude of different municipal services.

2.2 Smart city development and size

The requirements of vertical and horizontal integration, as well as the adoption of smart technologies to create smarter municipal services put larger requirements on the municipality. Both the number of inhabitants in the municipality and the degree of urbanization might impact smart city development in the municipality. Characteristics such as population size, management support, networks of peer institutions and resident demands have an effect on the benefit of e-government adoption [Chen and Kim, 2019]. Furthermore, there is an ongoing discussion within the smart city research on the applicability of the smart city concept to smaller communities.

According to the findings from Hosseini et al. [2018], small and medium-sized municipalities are not equipped with the same wide availability of infrastructure services as larger cities. Additionally, they do not have the same opportunities for economies of scale, nor the same range of opportunities for ecosystem collaboration with multiple actors. Many small and medium-sized municipalities also follow a "one-size-fits-all" technological approach which often fail because it does not match the property of the municipality [Hosseini et al., 2018]. However, the authors also argue that smaller communities are potentially able to move faster than large communities with innovative efforts due to less complex infrastructure and network of actors [Hosseini et al., 2018]. In example, broadband connectivity and external partnerships, especially with adjacent communities, are important success factors for smart city development in rural areas [Spicer et al., 2019], and smart city development can be used as a means to attract new industry as well as young professionals in order to counteract depopulation [Spicer et al., 2019].

Further, small, medium and large municipalities might have different views on the smart city concept [Desdemoustier et al., 2019]. Desdemoustier et al. [2019] suggest that the smart city concept can be viewed from a technological, societal, comprehensive or non-existent perspective. They found that small and rural municipalities often has no understanding or a technological view of the smart city concept, whereas medium and large municipalities more often develop a societal or comprehensive perspective. A municipality with a technological view of smart city development view a well-functioning infrastructure, as well as technology, as the most important aspects to become a smart city. In contrast, a purely human-centred view focuses on human capital and education. A municipality with a combination of the two understandings are categorized as integrative [Desdemoustier et al., 2019].

The smart city characteristics of the municipality might also be affected by the population size of the municipality. Borsekova et al. [2018] analyzes the functionality between the size of a city and smart city indicators. It compares large cities (100.000 - 500.000 inhabitants) with mega-cities (300.000 - 1 million inhabitants). The study uses a quantitative approach to identify the most important predictors of city size among 28 smart city indicators. The results indicate that compared to mega-cities, large cities tend to be more ecological aware, innovative and open minded. Even though Borsekova et al. [2018] analyze larger cities than the cases presented in this article, their results indicate that population size do influence the priorities of smart city development.

Further Raspotnik and Herrmann [2020] argue that the standardized smart city framework lacks focus on sustainability, and needs to be adjusted in order to be applicable for arctic cities. The aim of the framework is to be able to evaluate smart cities with low populations, peripheral development, remote locations and harsh climate conditions. According to Raspotnik and Herrmann [2020], smart arctic cities require an enhanced focus on sustainability in order to meet the challenges of climate change. The study is based on three arctic cities with a population from 50.000 - 300.000 people. General findings from Raspotnik and Herrmann [2020] is that a clear comprehensive strategy and external investments by businesses and foundations are important factors for smart city development in the arctic cities.

2.3 Governing smart city development

Governing smart city development requires that decision making processes, control of development initiatives, and project priorities involves all stakeholders so they build commitment and ownership of the final planning outcomes. In this context, the public authority plays the role of founder and regulator by bringing the interests of the different stakeholders together [Gohari et al., 2020]. With the public authority as a facilitator of smart city development in mind, Lee et al. [2014] identifies important dimensions of smart city governance; leadership, strategy, teams, management processes and principles, and performance measurement. They further argue that smart city initiatives cannot be run effectively without smart city leadership and a comprehensive strategic plan.

Ooms et al. [2020] further elaborate on the interaction between smart city development and innovation ecosystems, and states that smart cities resembles innovation ecosystems [Ooms et al., 2020]. An innovation ecosystem is a system of innovation networks where government, universities, industry, and non-governmental organizations participate to innovate new products and services [Carayannis and Campbell, 2009]. In a smart city context, the rationale of the innovation ecosystem is to find new solutions to specific problems in the city by initiating, importing, modifying and diffusing smart technologies [Dameri et al., 2016]. Further, the superior goal is to increase quality of life of the citizens in a sustainable manner [Ooms et al., 2020]. A related term to an innovation ecosystem is the quadruple helix model. The model describes how public authorities, academic institutions, firms and citizens interact in order to produce products and services relevant for the citizens [Carayannis and Campbell, 2009].

The interaction among the actors is characterized by each actor having a defined role in the system, however the inter-relations among the different actors varies. Academic institutions research to generate new knowledge, and can be viewed as knowledge intermediaries, knowledge gatekeepers, knowledge providers and knowledge evaluators [Ardito et al., 2019]. Firms produce innovation in the form of new organizational structures, as well as products and services in the market [Cavallini et al., 2016]. Additionally, the public authorities might collaborate with private firms in public-private innovation partnerships for service development, or private funding can be given for service and infrastructure development [Lee et al., 2014]. Further, the role of the public authorities is to create new policies and support the technological development [Cavallini et al., 2016]. Lastly, the citizens play a pivotal role in smart city development, both because "they are the main addresser of smart initiatives, and because their involvement and participation is often required for the complete success of a smart project" [Dameri et al., 2016, p 2978].

Smart city development is also affected by both formal and informal relations and processes. Gohari et al. [2020] have studied how governance in the form of roles and power in smart city initiatives has caused governance to emerge, change, and affect the goals designed by specific actors. According to their findings, the smart city projects were influenced by the informal interactions of outside actors. The actors involved in the smart city development used their interpersonal connections to integrate their expertise or influence the definition of the problem. Further, Ooms et al. [2020] have analyzed the importance of the different governance factors in the different phases of the evolution of a smart city ecosystem. They found that governance factors such as a common goal and a joint overall strategy and internal cooperation strategy have an effect on the ecosystem effectiveness in the initiation phase. In the growth face, where the ecosystem expands, the focus in the ecosystem is that of establishing external relations with other parties, such as competitors and suppliers [Ooms et al., 2020].

A challenge to smart city development is that the vision of the concept varies among the different actors in terms of technological, human and institutional factors [Dameri et al., 2016]. Universities often consider smart city "like an innovative place where to implement their pilots and experimental solutions". However, it is also found that universities "tend to neglect the digital divide, the difficulties in funding innovative facilities and the lack of competences in municipalities" [Dameri et al., 2016, p 2978]. Further, private companies might enforce their own solutions on the municipalities without considering the needs of the citizens. The municipalities on the other hand, struggles with strategic planning and change management for smart city development [Dameri et al., 2016]. In order to overcome this challenge, Angelidou [2014] suggest that municipal governments and authorities operating at the lowest tiers of government start by selecting a few domains or areas needed to be improved urgently.

3 The Nordic context

In order to understand the dynamics of smart city development in the Nordic countries, the governance structure and superior digitalization strategies of the different countries needs to be clarified. This section, will first present how the Nordic countries place in European digitalization benchmarks. Next, urbanization, national and regional influences, local autonomy and the approach to public innovation in the Nordic countries are discussed.

3.1 Digital benchmarks

This section presents three indexes benchmarking the digital performance of the Nordic countries. The E-Government Development index (EGDI) has been included as it measures the trends in e-Government worldwide [United Nations, 2018]. The Digital Economy and Society Index (DESI) has been included because it summarizes relevant indicators on Europe's digital performance and track the evolution of the competitiveness of EU member states [European Commision, 2019a]. Further, the 5G readiness has been included because measures the readiness of European countries to adapt 5G technologies [inCITIES Consulting, 2020a]. This index is of particular interest for smart city development as 5G is an enabler for future implementation of smart technologies in smart city development[GSMA, 2019].

Table 1 gives an overview of the scores of the Nordic countries in three selected indexes. The EDGI index has a range of 0 to 1, the range of the DESI index and 5G readiness index is 0 to 100. All indexes uses min-max normalization. Further description of the methodology of the indexes can be found in [United Nations, 2018, European Commision, 2019b, inCITIES Consulting, 2020b].

According to both EDGI and DESI, Norway, Finland, Sweden and Denmark are in the top tier of digital economies in EU/EØS [United Nations, 2018, European Commision, 2019a]. Additionally, the European region is far above the world average of 0.55 [United Nations, 2018]. All the Nordic countries are also considered to be far above the EU average when it comes to 5G readiness. According the 5G readiness index, Finland is the front-runner when it comes to implementing 5G and its related technologies. However, Denmark is considered to have the best innovative landscape, but lags behind on infrastructure and technology, being just above the EU average in this category [inCITIES Consulting, 2020a]. It is important to note that all the indexes are based on country-level findings, hence, they do not reflect the state of digitalization in the individual municipalities.

Table 1: EDGI, DESI and 5G readiness indexes. Source: EDGI, DESI and inCITIES

Index	Norway	Finland	Denmark	Sweden	EU average	Indicies
EDGI total	0.8557	0.8815	0.915	0.8882	0.7240	Online service index, telecommunication and infrastructure index human capital index
DESI total	66	69,9	68,8	69,5	52,5	Connectivity, Human capital, use of internet, integration of digital technology, Digital Public Services
DESI Connectivity	66,1	66,1	73,6	70,4	59,3	Fixed broadband, mobile broadband, fast and ultrafast broadband prices
DESI Digital Public Services	78	79,9	77,8	77,7	62,9	e-Government and e-health
inCITIES: 5G readiness total	64,08	70,95	65,93	65,91	53.03*	Infrastructure and Technology, Regulation and Policy, Innovation landscape, Country Profile, Demand
inCITIES: 5G readiness infrastructure and technology	62.53	67.44	51.18	56.58	49.19*	4G coverage, fiber coverage, internet bw per user, 5G commercial networks, # of IXP, # and maturity of 5G pilots, time to get electricity, 4G launch year, 5G spectrum auction plans
inCITIES: 5G readiness innovative landscape	56.21	64.24	65.52	68.00	43.98*	Companies with disruptive ideas, Growth of innovative companies, Researchers in R&D, R&D expenditure, university-industry collaboration, FDI and technology transfer, VC availability

***** Computed based on the data from the countries presented in the report.

3.2 Urbanization

The population growth rate strongly varies across the Nordic municipalities, with the largest cities and their surrounding areas having the highest population growth rates. The Nordic countries experience similar trends as the rest of the world, urban areas are experiencing a higher population growth rate than rural areas. In some cases, rural areas have even started to experience population decline. However, the concept of urbanization can be defined in multiple ways depending on the areas being compared. From the European perspective, the Nordic countries are sparsely populated. In 2016, only 45% of Nordic residents lived in what is defined as functional urban areas. On the other hand, more than 75% of Nordic residents lives in urban settlements with more than 2.000 inhabitants. Both functional urban areas and many urban settlements experience population growth. According to [Nordregio, 2019a], areas around Oslo, Stockholm, Copenhagen and Helsinki had the most intense population growth in the period 2011-2016. This includes municipalities situated within the functional urban areas that surrounds the largest cities.

The Nordic countries urban qualities in small and medium-sized cities have been prioritised as important areas of regional development. Even though people are moving to urbanized areas, it is not evident that urbanization is reserved the largest cities. Small and medium-sized municipalities have the potential to remain attractive places to live through development programs and municipal service improvement. Digitalizing to create better and more seamless services might prove an important step for small and medium-sized municipalities to increase their attractiveness [Nordregio, 2019b].

3.3 National and regional influences

All the Nordic countries are in the process of implementing national digitalization strategies where digital technologies are viewed as tools to realize local and national goals and focus on digitizing at a local level by responding to local challenges, needs and priorities [Nordregio, 2019b]. However, there are significant differences in how the countries govern digitalization efforts on a national level [Von Marion and Hovland, 2015].

The government structure in the Nordic countries is similar for all countries. It has a three level structure with national, regional and local authorities. Each level has a set of public responsibilities, however the responsibilities of each governmental level might differ among the countries. Similar to all countries is a high degree of local autonomy for the local authorities in the municipalities [Baldersheim et al., 2019].

There are several national organizations that influences the direction and focus of digitalization within the municipalities. Each of the Nordic countries has a municipal association with the core task of advocating the interests and development of municipalities and their partner organizations [KL, 2020, SKR, 2020, KS, 2020, Kommunförbundet, 2020]. In addition to the municipal organizations, all the Nordic countries have national agencies that advocate the direction of digitalization at a national level. In Denmark, Norway and Sweden, this position is hold by a dedicated national agency for digitalization. In Finland, however, it is the ministry of Finance that is considered to be the core policy provider for ICT and digitalization. However, there are some differences between these national digitalization agencies in the governance tools available. In Denmark, the Danish Agency for Digitalization has direct access to decision-making processes in municipalities, regions and state sectors through a budget negotiation role. While in Norway, Difi, is not directly involved but defines regulations and standards [Von Marion and Hovland, 2015].

The municipal association also support the municipalities in digitalization by creating superior goals and strategies [KMD - Norwegian Ministry of Local Government and Modernisation, 2019a, Sveriges Kommuner och Regioner (SKR), 2019, KL, 2019]. In Norway the Norwegian Association of Local and Regional Authorities (KS) and the Norwegian Ministry of Local Government and Modernisation (KMD) has formed and overall digitalization strategy for all governmental levels [KMD, 2019b]. While in Denmark and Sweden, the municipal digitalization strategy is created solely by KL (Denmark) and SKR (Sweden). In Finland on the other hand, there is no agency which holds the overall strategy for digitalization within the municipalities. However, The Finish Ministry of Finance is considered to be the core policy provider for ICT and digitization [Baldersheim et al., 2019].

3.4 Local Autonomy

The Nordic countries are characterized with regions and municipalities with high degree of local autonomy. In the European comparison, the Nordic countries distinguished themselves with a wide range of tasks and great organizational freedom. Local authorities in the Nordic countries have the freedom to organize themselves after local needs. Additionally, a large share of the municipal income is from local funding [Baldersheim et al., 2019].

Overall, Finland is considered to have the highest degree of local autonomy among the Nordic countries. When it comes to interactive governance, Finish local authorities have a stronger position than local authorities in Denmark and Sweden, but not as strong as for local authorities in Norway. In Norway, the municipalities have lower fiscal autonomy compared to the other Nordic countries due to stronger national regulations on taxation. Norway also has the most limited scope of local democracy both when it comes to financial autonomy; the freedom of the municipality to control financial resources, and functional autonomy; the ability to control the objectives and the goals of the local government. However, Norway has the highest scores in interactive governance, meaning that local government has as strong influence on national policy-making affecting the municipalities. Both Danish and Swedish municipalities have high functional autonomy, however, Danish municipalities have a lower financial autonomy than Swedish [Baldersheim et al., 2019].

3.5 Approach to public innovation

There are both clear similarities and clear differences on how innovation is approached in the Nordic countries. First, Sweden and Finland is considered to have a more overreaching and structural approach to innovation, while Denmark and Norway are more process and practical oriented towards tools to support individual organizations. Further, innovation projects in Norway are often activities outside daily service delivery, while direct development in operational activities has a larger focus in Denmark [KMD - Norwegian Ministry of Local Government and Modernisation, 2019b]. In Denmark, the Centre of Public Innovation support focus on innovation when public sector organizations collaborate with private actors. The organization also aims to increase the number of mature technological solutions and new technologies [COI, 2019]. Vinnova is the Swedish public organization for innovation, Innovation Norway and The Research Council of Norway have the same responsibilities in Norway, and in Finland the project Experimental Finland focuses on pilot projects in the public sector.

4 Methodology

In order to answer the research question "How is smart city development is organized in medium-sized municipalities in the Nordic region?", the multiple case study analysis is used as a research method. According to Yin. [2014] the case study is suitable to examine contemporary events. Further, the strength of the case study is its ability to deal with the full variety of evidence such as documents and interviews Yin. [2014]. The aim of multiple case study analysis is both to test the validity of existing theory, and to add to existing theory based on empirical findings [Mora et al., 2019]. The methodology consists of selecting the appropriate cases, collecting the data and analyzing the data [Mora et al., 2019]. Each of the steps are described in the following sections.

4.1 Case selection

In multiple case study analysis, there are three main criteria for case selection; the cases should have characteristics which enables them to be viewed as one entity, a quintain, the cases should provide diversity across the context, and they should "provide the opportunity to learn about complexity and context" [Stake, 2013, p.23].

In order to fulfill the first criteria of Stake [2013], all the case-municipalities chosen are of medium-size. For this article medium-size is defined as population size of 20.000 to 60.000 inhabitants. This is selected as the unifying criteria for several reasons. First, the size interval is set to include case-municipalities which are large enough to have initiated their own smart city projects, but small enough to have different demographic, social and economic characteristics than larger cities. Second, as stated in the introduction, smart city development in medium-sized cities is less researched than in larger cities. Third, as elaborated in section 3.2, the Nordic countries focus on development programs and service improvement in small- and medium-sized municipalities.

Table 2, shows the fraction of the country population who are living in medium-sized municipalities, as well as the fraction of the total number of municipalities which are of medium size. Even though most of the citizens of the Nordic region lives in what is considered to be large municipalities, a substantial fraction lives in medium-sized municipalities. Hence, the medium-sized municipalities are chosen for two reasons. First, because of their potential to remain attractive areas to live which diversify economic growth through regional business development. Second, because they face different challenges in terms of social, economic and environmental sustainability compared to larger cities [Nordregio, 2019a].

Table 2: medium-sized municipalities and their population as a fraction of total population.

Size	# municipalities population 20' - 60'	% of total number of municipalities classified as medium-sized	Population in medium-sized municipalities as % of total country population
Denmark	65/98	66%	48%
Finland	39/310	13%	23%
Norway	48/356	13%	29%
Sweden	85/290	29%	29%

Next, in order to provide diversity across context, one municipality from each of the countries Norway, Sweden, Denmark and Finland is selected. Hence, how smart city development in medium-sized municipalities is organized is mapped across country contexts. Even though the Nordic countries have many similarities in terms of social, economic and governmental factors, they also have differences. Some of these differences are outlined in the background chapter in section 3. The section describes that there are nuances in national and regional influences on digitalization, local autonomy and approach to public innovation.

Lastly, in order to consider the opportunity to learn about the complexity and context of smart city development, two selection criteria are considered. First, the municipalities are in a sample of ten promising municipalities from each country. The municipalities were pointed out as promising for smart city development by domain experts. Secondly, the municipalities use or have used some kind of smart technology, but do not need to have a smart city strategy. Out of the ten municipalities from each country, the municipality pointed out by the domain experts as the most promising in terms of smart city development was chosen. By selecting the leading cases the aim is to identify best practices for smart city development in medium-sized municipalities.

4.2 Data Collection

After settling on the case-municipalities, the websites of the municipalities were used to identify the digitalization or smart city leader in each municipality. Initial contact was made, the aim of the research was presented and a date for the interview was settled upon. Before the interviews, information about the four cases were collected through websites, reports and articles available online. Hence, we had knowledge about several areas of the smart city development in the selected cases before the interviews were held. Next, a one hour semi-structured interview were conducted with the smart city manager or digitalization manager in each of the municipalities. The interview template can be found in appendix A. Based on the template, the same general open-ended questions were asked in all of the interviews. However, minor adjustments to the interview questions were done during the interviews in order to make it more relevant for each case. The interviews were conducted in April 2020. For the Norwegian case-municipality, our interviews supplement previous interviews, conducted in 2019 by the connectivity company Telenor. All municipalities also received a follow up e-mail with questions to be answered to supplement the analysis. All the digitalization managers responded to this email.

According to Stake [2013], the context in which the cases appear, influences the choices made and the activities initiated within each case. Thus, in addition to the interviews, secondary data about national and regional influences has been collected. This includes global, European and Nordic digitalization indexes, national digitalization strategies for the Nordic countries, and different reports on the state of smart city development and digitalization in the Nordic countries. Table 3 gives an overview of the type of data collected, as well as the related informants and authors.

Table 3: Overview of interviews and secondary data.

Data format	**Description**	**Sources**
Interviews	4 interviews with 5 informants from 4 municipalities	Development -and smart city department leaders IT-department leaders Mayor
Documents	National and regional digitalization strategies in the Nordic countries Reports comparing the Nordic countries on digitalization, innovation and governance	National governments, Nordregio, Norwegian association of Local and Regional Authorities, Nordic Innovation, Rambøll, Struense & Co
Statistical data	Digitalization and smart city indexes Municipal statistics in the Nordic countries	EU, UN, inCities Consulting, IMD World Competitive Center, Eden Strategy institute Statistics Norway, Statistics Finland, Statistics Denmark, Statistics Sweden

4.3 Data analysis

According to Yin. [2014], following theoretical propositions is the preferred analytical strategy for case study research. Thus, in order to answer the research question "how is smart city development organized in medium-sized municipalities in the Nordic region?", an analytical framework has been established. The framework was created to be able to organize and compare the empirical data from the four cases, and was established by considering the applicability of existing theoretical frameworks to the empirical data. Based on the assessment of the applicability of previous theories, we settled on four dimensions with related sub-dimensions. The four dimensions are; the municipalities' understanding of the smart city concept, smart city governance, smart city collaboration and smart city resources. An overview of the analyzed dimensions and their related sub-dimensions is shown in table 4. The subsequent paragraphs explain the relevance of each dimension to the research question.

Table 4: Dimensions and sub-dimensions of the analytical framework.

Dimension	**Sub-dimensions**
Smart city concept	Human-centric, Technological, Integrative, None
Smart city governance	Goals and strategies, project initiator, organizational setup, project selection criteria, motivational drivers
Smart city collaboration	Businesses, academia, citizens, inter-municipal, regional and national, strategic facilitator
Smart city resources	Mobile network deployment, financing

The municipalities' understanding of the smart city concept is relevant for how smart city development is organized in the municipality as it affects the priorities of the municipality when it comes to smart city development. This especially has an effect on the municipalities without a clear orientation on the smart city concept, and thus do not see the relevance of the concept for their territories [Desdemoustier et al., 2019]. The municipalities' understanding of the smart city concept is viewed to be either technological, human-centred, integrative or non-existent, where each type of understanding result in different priorities [Desdemoustier et al., 2019]. Further, this dimension is of interest as small, medium and large municipalities tend to interpret the smart city concept differently [Desdemoustier et al., 2019].

Smart city governance is defined by the institutional governance structure and impacts the sources and use of resources for smart city development in the municipality [Lee et al., 2014]. Further, the output of the governance is the activities performed in relation to smart city development [Ooms et al., 2020]. Hence, smart city governance provides valuable information to how smart city development is organized. According to Lee et al. [2014], the important sub-dimensions to map when it comes to smart city governance is leadership, strategies, management processes and performance measurement. These dimensions of governance has been studied in larger cities, but how smart city governance is organized in medium-sized cities is less known. Hence, in the smart city governance dimension, we identify the presence of a smart city strategy, as well as short and long term goals. In terms of leadership, management processes and performance measurement we identify the project initiator, the organizational setup as well as project selection criteria. Additionally, we map the motivational drivers for smart city development in each municipality.

In addition to the municipal governance structures for smart city development, collaboration with external actors is an important aspect in terms of how smart city development is organized [Ooms et al., 2020, Ruhlandt, 2018]. The actors include those in the quadruple helix [Cavallini et al., 2016], which in addition to the municipality are businesses, academia and citizens. Further, horizontal relationships in the form of inter-municipal collaborations were mapped as such collaborations has been identified to appear when municipalities with more limited resources do smart city development [Spicer et al., 2019]. Additionally, collaboration with regional and national actors were mapped to also include vertical collaboration aspects [Ruhlandt, 2018]. Additionally, we mapped the presence of a strategic facilitator for smart city development.

Lastly, the smart city resource dimension was added as resources in general are regarded as critical for value generation [Osterwalder and Pigneur, 2010], and is thus considered to be an underlying factor for smart city development. Additionally, smaller municipalities are characterized with more limited resources than large ones [Hosseini et al., 2018]. Hence, smart city resources are of relevance to how smart city development is organized in medium-sized municipalities. More specifically, core assets for smart city development are resources such as information technology and financial resources [Wirtz et al., 2019]. In our analysis, we have focused on the mobile network deployment, and more specifically deployment of networks designed for IoT-implementation. In the financial resources dimension, we have focused on how smart city development projects are funded.

4.4 Case Descriptions

DM is located in a rural region of Denmark and has a population of approximately 50.000 inhabitants living in several urban settlements within the municipality. Green industries are important contributors, and several green industry players have facilities located in the municipality. The main part of smart city development in DM has evolved around a founded project in one of the municipal villages. However, the project was ended before it was finished due to lack of political support. Many of the sensors installed during this project is now out of order, however the LoRa-network installed during the project is still active. The municipality do not have a smart city strategy, but smart technologies are mentioned as a part of the development strategy. Currently, the municipality only has one smart project within elderly care which is in a very early pilot stage.

FM also has a population of approximately 50.000 inhabitants and is situated close to multiple larger cities, in an urbanized region of Finland. The ICT industry has a long history in the municipality, and today the municipality has an IoT-campus housing academic institutions, as well as R&D facilities and production areas for companies. Initially, the main focus of smart city development in the municipality was to create jobs. However, the municipality has recently started to focus on more citizen-centric perspectives of smart city development. The municipality has a smart city strategy, a long term goal for smart city development and multiple ongoing smart city projects.

NM has approximately 30.000 inhabitants. NM is located in an urban region of Norway, close to a large city. The most important industry players in the municipality are engineering, wood processing and pharmaceutical industries. The Smart city-program of NM stimulates experimentation, testing and demonstration of new technology, new services for citizens and new types of business models to create value for a more forward-looking society. Hence, the municipality both has a smart city strategy and a long term goal for smart city development. Currently, the municipality has multiple ongoing smart city-projects.

In *SM* there lives approximately 40.000 people. The municipality is situated in a rural region of Sweden, but close to a large city. Important industries in the municipality are wood industry, metal- and engineering industries. The Swedish municipality is mainly focused towards digitalization and do not have a smart city strategy, nor projects which they define as smart city projects. The municipality has focused on creating a municipal platform that enables the municipality to collaborate on digitalization projects with other municipalities. The platform includes collaboration with other municipalities on system maintenance and broadband infrastructure. In terms of smart city-related projects, an energy provider in the municipality has built a LoRaWan-network, which is currently only for testing purposes.

5 Analysis

The analysis consists of four dimensions with related sub-dimensions where the aim of each dimension is to describe different aspects of how smart city development is organized in medium-sized municipalities in the Nordic region. First, the understanding of the smart city concept is analyzed. Next, aspects of smart city governance is analyzed to describe how smart city development is organized internally in the municipality. Then the municipalities' relationships with external actors are presented, focusing both on external actors in the quadruple helix and public horizontal and vertical relationships. Lastly, the smart city resource analysis maps the state of the mobile network deployment and the financial resources for smart city development in the municipalities.

5.1 Understanding of the smart city concept

How the municipality understand the smart city concept might have an effect on how smart city development is organized. As presented in section 2.2, the municipal understanding of the smart city concept might set the priorities and direction of smart city development. Hence, the understanding of the smart city concept of each of the case-municipalities is outlined in this section.

It is challenging to give a precise description of the understanding of the smart city concept in the Danish municipality. In the interviews, DM defines smart city development as a way of improving the quality of life of citizens by focusing on the citizen's needs. Sensors and network deployment in the municipality is only considered smart city if it creates value for citizens. Smart city development is viewed as a means to make citizens stay in the municipality and not move to larger cities. This view is in line with a societal view of the smart city concept where the municipality aims to become a smart city based on people, sustainability and governance [Desdemoustier et al., 2019]. However, the municipality chose to end their smart city initiatives due to lack of political support and change in administrative priorities.

Historically, the Finnish municipality has had technological view of smart city development. The municipality defines smart city as way of using technology to solve problems. This technological view of smart city development is rooted in the presence of strong ICT industry in the municipality. However, FM has recently started to include the softer sides of smart city development, in example that data can be analyzed for the sake of well-being of the citizens. The municipality was introduced to the societal perspective of smart city development when participating in a Nordic collaboration program for municipalities.

The Norwegian municipality NM has an integrative view of the smart city concept. The focus of smart city development includes lowering costs of municipal services, provide work for citizens and also provide projects for startups. The municipality also add short and long term sustainability as an important aspect of smart city development. Lastly, citizen engagement in development projects is considered to be important. Hence, both the technological and societal aspects are considered in the smart city development.

The Swedish municipality SM do not define themselves as a smart city. They do not consider smart city as an applicable concept to their municipality. In their view, smart city development is more fit and easier to run in larger cities. However, the recent focus of the municipal administration has been to create a strong platform for digitalization and development of municipal services. Further, the municipality has some projects involving smart technology. However, these projects are not branded as smart city.

5.2 Governing smart city development

In the smart city governance dimension, we analyze how smart city development is organized internally in the municipalities. We analyze the presence of a smart city strategy and the short and long term goals. Further, in terms of leadership and management processes, we identify the project initiator, the organizational setup as well as project selection criteria. Lastly, the motivational drivers for development in the municipality are analyzed. An overview of smart city governance in the Nordic municipalities is shown in table 5.

Table 5: Overview of smart city governance in the municipality.

Municipality	***DM***	***FM***	***NM***	***SM***
Smart City Strategy	No*	Yes	Yes	No
Long term goal	Yes	Yes	Yes	No
Project initiator	The municipal departments	Companies	Companies, academic institutions, the municipality	Local company
Organizational setup	Unorganized, Projects need to be approved by the digitalization and ICT department	Unorganized, one person working full time on smart city development	A central project group as well as project leaders within each department	Non-existent for smart city
Project selection criteria	Projects are selected based on its potential for value capture, both qualitatively and quantitatively	Low budget, Small projects, Aligned with everyday goals	Sustainable, collaboration with multiple actors, uses technology in an innovative way	Development projects are prioritized by a committee
Motivational drivers	An aging population, Increase level of service to citizens, Provide the same quality of service at a lower cost	Create new jobs, attract new citizens	An aging population, increase level of service to citizens, provide the same quality of service at a lower cost, environmental friendly solutions, business development	An aging population, Depopulation, Provide the same quality of service at a lower cost

***** The municipality do not have a smart city strategy, but smart technologies are mentioned as a part of the development strategy.

DM has no long term or coherent smart city strategy. However, the municipality has an overall development strategy which includes goals of improving the digital infrastructure and using smart technologies to develop municipal services. The organizational setup for smart city development is considered to be unorganized, there is no structure and no one with a dedicated task of smart city development or exploring new technology. Each municipal department is responsible to identify how new technology can be used in their department. However, the different departments in the municipality have to involve the ICT department for all digitalization projects to make sure that security and open data requirements are met. DM considers both the quantitative and qualitative value contribution when initiating new projects. The main motivational drivers for smart city development in the municipality is to increase service to citizens in a sustainable and economical way, as well as providing the same quality of service at a lower cost. DM also has challenges related to an aging population, however, this is not explicitly mentioned as a driver for smart city development.

FM has a smart city strategy focusing on smart mobility an transportation concepts as well as living environment concepts. The municipality is known as a great location for businesses to do smart device R&D, however the goal of the municipality is to also be known as a smart city. However, no coherent smart city program has been launched. Only one person works full time on smart city development, but around 10-15 people touch upon smart city development in projects or their everyday work. In terms of initiating new smart city projects, it is the companies that approach the municipality with new ideas. Smart city projects are selected based on budget size and alignment to everyday goals. The municipality prefers projects of low budget due to limited financial resources. The experience is also that smaller projects are less affected by political agendas in the municipality, and are easier to complete. The motivational drivers for smart city development in FM is mainly to create new jobs.

NM has worked systematically through the years to develop its smart city strategy. The smart city program in the municipality was initiated as a consequence of a poor financial state of the municipality. In order to improve the financial situation of the municipality, NM hired experts on smart city and digitalization to establish new goals and a new direction for digitalization. Today, the long term goal of smart city development in the municipality is to develop a sustainable, modern society where economical, social and environmental values are at the centre.

Further, NM has focused on having a clear and structured setup of the smart city program. The program has both a central project group under the development department, as well as project leaders for smart city development in the different municipal departments. The project leader in the department is responsible for the progression of the innovation efforts in the department, whereas the central project group is responsible for communication between departments and for making superior strategic decisions. Smart city projects are selected based on a set of overall criteria, namely being sustainable both in the short and long term, the project has to involve multiple actors and technology has to be used in an innovative way. In addition to the overall project selection criteria, the different project ideas are scored in order to make them comparable for selection. The municipality has recently started to use a digital platform where all project ideas and their related score can be found and the progress of initiated projects is tracked. The motivational drivers for smart city development was initially to lower the cost of service provision in the municipality. However, the motivational drivers have evolved to include business development in the municipality, handling an aging population and increase the level of service to citizens.

As mentioned, SM do not consider themselves as a smart city, and they do not have a smart city program. However, the municipality have a clear strategy for creating a municipal platform for digital development. The platform have three main areas: (1) Collaboration with multiple other municipalities on the development of e-services, (2) System maintenance to handle security issues and (3) Development of infrastructure and broadband network deployment. When this platform is set, SM views itself as able to initiate larger projects. However, the municipality has not yet defined any goals which measures the effect of initiated projects and changes. Digitalization and organizational change is organized as a dedicated project office with a project manager leading the office. However, the municipality do not have something similar for smart city development. New development projects are selected by a committee which prioritizes the projects. Other projects are decided by the different departments or by politicians depending on the scope. The motivational driver behind digitalization in the municipality is to cope with challenges such as an aging population, depopulation and creating more efficient services.

5.3 Smart City Collaboration

The Smart City Collaboration dimension analyzes how collaboration with external actors is organized in medium-sized municipalities. Both collaboration with quadruple helix actors and public vertical- and horizontal relationships are analyzed. Collaboration with quadruple helix actors refers to collaboration with businesses, citizens and academic institutions. While public horizontal relationships refers to how the municipality collaborate or coordinate with other municipalities. Public vertical relationships refer to how the municipalities get support, collaborate or coordinate with regional and national public organizations. An overview of how collaboration with external actors is organized in the four case-municipalities is given in table 6.

Table 6: Overview of collaborating actors on Smart City Development.

Actor	**DM**	**FM**	**NM**	**SM**
Strategic facilitator	None	None	Hired experts to help develop the digitalization and smart city strategy	None
Businesses	Finds it easier to work with small companies	IoT Campus, Prefer to collaborate with local companies as partners for innovation	Large companies considered the most important partners for innovation	The local energy company
Academia	Universities invited to test technologies, Student projects	Collaborates with two universities in neighbour municipalities.	Research projects, student projects	IT-programs in local higher vocational education
Citizens	Workshops	Questionnaires, Workshops	City Lab, Questionnaires	No specific communication for smart city development
Inter-municipal	Unorganized, participates in a forum for exchange of experiences with 17 municipalities	Unorganized, participation in an inter-municipal forum of Nordic municipalities	IoT-project with neighbour municipalities, Regional common IT-architecture project	Non-existent for smart city development, Collaborates with multiple other municipalities on digital service solutions
National and regional	KL/KOMBIT, National support on digital network deployment, Regional Partnership network	Kommunforbundet, Nordic smart city forum	KS, National smart city development support, National innovation programs	SKR, National smart city development support, National innovation programs

Smart city collaboration in DM

In terms of collaboration with quadruple helix actors in smart city development, DM has collaborated with both businesses, academic institutions and citizens. DM has collaborated with both small and large companies on smart city development. However, they find it easier to collaborate with smaller companies because the distance from idea to decision is shorter in such collaborations. Collaboration with universities includes projects where researchers get the opportunity to test technology in the municipality and student projects where the students design services for the municipality. Further, the municipality interact with citizens on digitalization projects using questionnaires and seminars.

DM also coordinates and collaborate in inter-municipal networks and get support from regional and national public organizations. However, collaboration with other municipalities is considered to be unstructured. The municipality do participate in an inter-municipal forum with 17 other municipalities in the region. Representatives from the municipalities meet 3-4 times a year to exchange general experiences and to make policies on how to treat and implement services of private actors. In terms of national and regional collaboration, DM is in the early phase of establishing a smart device project in the health sector in collaboration with the municipal innovation organization KOMBIT. Additional national support is first and foremost related to the national broadband and connectivity strategy which aims at improving the digital network deployment in all Danish municipalities. Regionally, the municipality participates in a partnership network for knowledge sharing. Participating actors are municipalities, businesses and knowledge and research institutions. The main goal of the partnership is to ensure green transition and growth in the region. However, the network also focuses on smart city and smart communities. Regarding smart city development, the main focus of the network is to discuss new technologies and how they can be implemented. However, few representatives from DM has participated in the network.

Smart city collaboration in FM

As in DM, FM collaborates with all actors in the quadruple helix where most of the helix collaboration is centered around an IoT campus in the municipality. The campus is an arena where businesses can meet, and it has both production areas and R&D-facilities. The goal of the campus is to create a good surrounding for innovating new ideas. Some of the companies located at the IoT campus also work with the municipality to test the technology of the company and innovate together with the municipality. Further the IoT campus also houses scientists and educational institutions. The municipality collaborates with universities in neighbour municipalities, and one of the universities also has facilities and study programs situated in the IoT campus. Regarding citizen engagement, the municipality uses both questionnaires and workshops. However, FM experience that citizens are not able to give good answers on the spot. The municipality find citizen engagement challenging because they are not able to engage the citizens in the initial phases of a project, which sometimes result in complaints when the effects of the project becomes visible.

Similar to DM, FM's collaboration with other municipalities is unstructured. However, the municipality looks internationally for inspiration to smart city development. When the municipality created the IoT campus, they looked internationally to similar facilities to get inspiration. The municipality has also participated in a smart city program together with other municipalities in the Nordic countries. Further, the municipality plans to collaborate with the local telecommunication company which has several municipal owners on a smart city project. Nationally, the Association of Finnish municipalities provides a platform for benchmark purposes and knowledge sharing. The solution can be used to communicate with other municipalities. The municipality can both present its results and achievements, but also ask other municipalities about their experiences. However, FM report that they have not had the capacity to use the platform actively. The municipality has also participated in a Nordic smart city forum with one municipality from each of the Nordic countries. It was through this forum, that the municipality adapted a more human-centric understanding of the smart city concept.

Smart city collaboration in NM

In contrast to the other municipalities, NM has for many years collaborated with a facilitating organization providing support for smart city development. The facilitating organization has helped the municipality to plan, initiate and implement their smart city-program.

Further, NM also collaborate with all the actors in the quadruple helix. Both academic institutions and companies approach the municipality with smart city projects where they want the municipality as a partner. Hence, the municipality has to prioritize requests for new projects. In terms of partners for innovation, the company prefer to collaborate with large actors, both private companies and academic institutions. However, this is partly because there are few local companies delivering services for such projects. In terms of collaboration with academic institutions, the municipality collaborates on both research projects and student projects. Further, citizens have been engaged by using questionnaires. The goal of the questionnaires is not to find new projects, but to help the municipality guide selected projects in the right direction. However, the municipality has also recently opened a City Lab. This facility is supposed to be an overall organization for smart city, but also an arena for citizens to participate in smart city development.

When it comes to collaboration with other public actors, NM has several inter-municipal collaboration projects. The municipality has collaborated with two neighbouring municipalities on an IoT project. Further, the municipality is part of a formalized collaboration network where municipalities in the region are collaborating to create a common IT-architecture. The organizational setup for this collaborative project is a secretary of three people, a steering group where all the municipal counselors are present and a coordination group consisting of digitalization-leaders and directors in the municipalities. The goal of this collaboration is to create a common IT-architecture. The project has proved to be challenging as it limits the type and amount of individual projects a municipality can do.

Smart city collaboration in SM

In relation to smart city development the only project of SM is the implementation of a LoRa-network done by the local energy provider. However, this section also outlines the municipality's relationships to external actors on digitalization, as it can prove relevant for smart city development in the municipality in the future.

For digitalization, the municipality collaborates with both businesses and the local higher vocational school. Regarding collaboration with businesses, SM considers it as easy to build networks of organizations and companies. One example is a 5-year development program where local businesses and the municipality together created a strategic document that describes what is expected by the local businesses and what is expected by the municipality. Further, a set of IT-study programs were established at the local higher vocational school in order to meet the need for more digital competence both among local companies and the municipality. Today, the higher vocational school educates digital specialists which are recruited both by the municipality and the local companies. The municipality further has some communication with universities in neighbouring municipalities, however, this is more focused towards general municipal development and education. In terms of citizen participation, the municipality has continuous citizen dialogue and a routine for citizen engagement and ideas, but do not have specific programs for citizen engagement related to smart city development or digitalization.

SM collaborates both vertically and horizontally with other public organizations for digitalization, but not for smart city development. Regarding inter-municipal collaboration in the field of digitalization, SM participate in a national network of municipalities where project ideas and experiences are shared. An advantage of the network is that it provides the municipality with ideas from municipalities located far away geographically. In example SM has, by being a part of the network, discovered a digital process, developed by another municipality, which it wants to buy. In addition to participation in the national network of municipalities, SM collaborates with multiple neighbouring municipalities in the region on developing e-service solutions. Regarding vertical relationships, the national municipal association SKR supports SM by providing the municipality with recommendations on standardization and how to build the municipal infrastructure. However, they do not provide plug-and-play solutions, which have to be developed locally.

5.4 Smart City Resources

The last dimension of the analysis is the availability of resources for smart city development. According to Wirtz et al. [2019] the core assets for a municipality to become smarter is the information technology infrastructure and the financial resources. Hence this section outlines the mobile network deployment and the financial resources available for smart city development in the municipalities. Table 7 gives an overview of the mobile network deployment for smart technologies in each municipality.

Table 7: Overview of sensor networks in the municipalities.

Network	**DM**	**FM**	**NM**	**SM**
LoRaWan	Yes	Yes	No	Yes
NB-IoT	Yes	Yes*	Yes	No
Sigfox	Yes	No	No	No
5G	Planned	Planned	Planned	Unknown

***** The network is currently for R&D purposes.

Mobile network deployment

In DM, broadband network connectivity for citizens is still under construction in the rural parts of the municipality. The municipality is behind many other danish municipalities on broadband connectivity, but a new fiber network is currently under construction. There are, on the other hand, several actors providing LPWAN-networks that meet the IoT requirements. The municipality has several applications are currently being processed for 5G and narrowband antennas. In addition, the municipality has a LoRa-network used to transmit data related to district heating in one of its villages. Lastly, the Danish Sigfox operator IoT Denmark has deployed its LPWA-network in the municipality.

FM has a LoRa-network initiated by a local company. However, the network is still in a testing phase where it is used for experimental purposes. The network has been deployed as a mutual test project; the municipality provides locations for LoRa-antennas, and data which the provider can test the network on, while the municipality transmits the data for free. There are also companies testing NB-IoT technology in the municipality, however, they have their own RD facilities and has not involved the municipality in their projects.

NM has installed a NB-IoT network in order to transmit data from sensors in the municipality. Currently most sensors connected to the network are only used in pilot projects for smart city development. However, the sensors are used in multiple different municipal departments such as water and sewage, renovation, air quality and pollution. Deployment of fiber networks in the municipality is challenging because of the scattered settlements outside the city centre.

SM has a LoRa-network built by the local energy company. The network is still in a R&D-phase where the company is doing different pilot projects and tests with a lot of different suppliers and companies. The goals is to be able to do larger projects in the future. The deployment of the network is outsourced to the energy company, which also make the strategic decisions. In example, the municipal administration was not involved in the choice of network technology. The broadband infrastructure in SM is considered to be well-deployed, broadband network deployment is expected to be finished in short time.

Financial resources and funding
In term of financial resources, projects in DM are funded by the different departments, and there is no dedicated funding for smart city projects. However, the departments can apply to the municipal board for funding if the business case of the project is good. The municipality has received funding for a large scale smart city project involving multiple actors. Sometimes public utilities that provide services to the municipality also contributes with funding to smaller projects.

FM has few financial resources for smart city development. The municipality also prefer smaller smart city projects that are considered as innovation projects where the procurement process is less regulated. However, regional or national organizations might support smaller projects. The municipality has received national funding for digitalization of governance.

NM uses test projects and innovation projects as an opportunity to spend less of the municipal budget on innovation projects. Companies test their technology with the municipality, but the municipality do not necessarily need to invest from their own budget in the project. The municipally has also received funding from national or regional innovation -and regional innovation programs.

Most projects in SM are financed by the organization initiating the project, however, some projects are financed by the municipality centrally. In both cases, the municipality aims at applying for external financing, as well as external collaboration if possible. Proof-of-concept and early test projects can also seek financial support from development budgets.

6 Discussion

The aim of this paper is to analyze how smart city development in Nordic medium-sized municipalities is organized and assess how it is influenced by contextual factors. Our aim has been to take a coherent approach by analyzing the governing and collaborative structures of smart city development in the selected cases. In this section, we compare our results to existing literature on smart city governance. Additionally, we discuss the contextual factors local autonomy, local conditions and the country-level approach to public innovation and digitalization.

6.1 Governing smart city development - cross case comparison

Previous literature on governing smart city development enhances the importance of a clear strategy, expectation management and communication both internally and among all stakeholders in order to succeed with the implementation of smart city projects [Dameri, 2014, Argento et al., 2019, Ooms et al., 2020, Gohari et al., 2020]. The empirical findings from our selected cases support this view, and it becomes clear by comparing the differences in how smart city development is governed.

The maturity of the smart city development differs among the four cases analyzed. This becomes evident by relating our empirical findings to the study of Ooms et al. [2020], which traced the evolution of governance structures in a dutch smart city initiative. An important finding by Ooms et al. [2020] is that the governing of smart city development changes over time. In the initiation phase, the focus of smart city governance should be on building relationships, while the growth phase increases the need for setting, advocating and checking performance measures [Ooms et al., 2020].

First, the project initiator might influence the strategic direction of smart city development in the municipality. In three out of four municipalities, private companies are the initiator of new projects. According to Gohari et al. [2020], the interest of private sector partners in smart city development is innovation, economic interest and increased knowledge about their technology. Further, Dameri [2014] argue that private companies might neglect the needs of the citizens, prioritizing their own technical solutions. Hence, the municipality needs to have the organizational ability to ensure that public interests and citizen needs are met in the initiation phase of the project.

This enhances the importance of the municipality taking the lead of smart city development, setting clear goals and strategies to establish formal platforms for collaboration [Gohari et al., 2020]. The alternative, informal networks with fragmentation of responsibilities, make smart city planning complex, ambiguous, and uncertain [Gohari et al., 2020]. Both in FM and NM, private companies approach the municipality with new ideas for projects, and in SM, a local company has taken the lead on the only smart city project initiated. However, the municipalities ability to establish formal platforms for collaboration differ. NM has a central smart city leader and committee, as well as smart city project leaders within each municipal department, and is using a digital project evaluation tool to track the progress and performance of initiated projects. FM on the other hand only have one person dedicated to smart city work, and the smart city leader reports lack of focus on smart city in other parts of the organization. Lastly, SM has created a platform for collaboration among 14 municipalities on digitalizaton projects, and see this as a foundation to further built on. However, their only smart city project, implementation of a LoRa-network, is solely driven by the local energy company which makes the strategic decisions. Hence, SM do not take the lead on smart city development in the municipality, even though they have a strong collaborative platform for digitalization. The degree of a formalized organizational setup in NM suggest that the municipality has entered the growth phase of smart city development, while FM and SM is in an initiation phase.

According to Ooms et al. [2020], municipalities with smart city ecosystems in the growth phase has governance elements linked to transactional leadership. This includes co-creation strategies, dedicated formal organizations for smart city and large focus on performance measurement. Further, the importance of more formalized governance in the growth phase might be important to be able to handle more complex challenges. NM states that their main upcoming challenge for smart city development is related to storing the data when the number of sensors go from a few tenths to several thousand, and coordination of several data sources is needed. Hence, the formality of the governance structures might be of importance in order to handle the interests of all stakeholders when the complexity of the technology and systems used for smart city development increases.

Another interesting finding is that NM has, unlike the other municipalities, used a strategic facilitator to establish both a smart city - and a digitalization strategy. Hosseini et al. [2018] arguing that small towns in Germany, which are comparable to medium-sized municipalities, require stronger guidance than large cities to define the appropriate smart city strategies. We argue that the use of a strategic facilitator in the initiation phase might have accelerated the smart city development into the growth phase and ensured a more continuous process of smart city development in NM compared to the other municipalities.

FM, on the other hand is in an early stage of smart city development, however, the municipality has several characteristics to succeed in their efforts to become smart. The initiation phase of smart city development involves sense-making, resource-gathering and establishment of organizational structures [Ooms et al., 2020]. The enabling governance elements in the initiation phase should be to strengthen internal relations, cooperation strategies and goal setting. FM has both a common goal and a joint strategy for smart city development. Additionally, in terms of cooperation strategies, the IoT campus located in the municipality can be considered an innovation cluster [Russell and Smorodinskaya, 2018]. Firms and organizations involved in clusters have been found to be more dynamic than those outside, and the proximity effects of the cluster can "improve the competitiveness of both the group of participants and the territory of its location" [Russell and Smorodinskaya, 2018, p.118]. Hence, the presence of the IoT campus might prove itself a valuable resource for further smart city development in FM. However, because only one person is dedicated to smart city development in the municipality, only small projects with low budgets and few actors are chosen. In order for the municipality to enter the growth phase of smart city development, the establishment of a formal organization for smart city development might be needed [Ooms et al., 2020, Lee et al., 2014].

Additionally, FM sees project scaling as the main inhibitor for advancing smart city development where smart city innovations and procurement of large scale solutions are two disjoint and separate processes. The issue of scaling smart city projects has been problematized by Taylor Buck and While [2017] who states that smart city development "overlooks the roll out of the smart city through multiple incremental and smaller steps" [Taylor Buck and While, 2017, p.504], and that "evidence suggests that smart city innovation is most evident through well-funded niche experiments in a limited range of urban contexts" [Taylor Buck and While, 2017, p.504]. Based on the empirical findings in FM, we argue that project scaling require increased attention in the initiation phase of smart city development in order to create projects that are not terminated at a piloting stage.

In the case of DM the smart city projects were ended due to lack of political support and coordination among the participating actors. Some of the initiated innovation projects in the smart city program were integrated in the municipal operations. However, most of the projects ended in its pilot phase. This can be explained by the lack of process owners, horizontal accountability and cooperation among all involved parties [Argento et al., 2019]. This is supported by Dameri who states that "Without a central direction, coordinating the interest of all the key actors with the stakeholders expectations and needs, the smart city will remain an interesting innovative laboratory, but failing in creating public and private value for all in the long term" [Dameri, 2014, p.2979]. The measures taken to overcome these challenges should be comprehensive, integrated strategies to support long-term profitable and effective smart projects [Dameri, 2014].

In conclusion the empirical and literature findings suggest that smart city development is dependent of the maturity of smart city governance in the municipality. In order for the case-municipalities to succeed with smart city development in the long term, clear goals and strategies, as well as platforms for collaboration are needed. In addition, support from a strategic facilitator in establishing the goals and strategies might be of importance for medium-sized municipalities due to their more limited resources. In addition, a strategy for scaling pilot projects needs to be present from the start, this way the smart city projects are more likely to create value in the long term and not remain experimental projects with limited impact.

6.2 The influence of contextual factors on smart city development

In this section we discuss to what extent contextual factors might have an effect on the smart city performance of the case-municipalities. We compare our findings to results from country-level reports regarding local autonomy [Baldersheim et al., 2019, Struensee Co, 2017], approach to public innovation [KMD, 2019], and the national digitalization ecosystem [Von Marion and Hovland, 2015]. According to Ruhlandt [2018], the influence of contextual factors on smart city development remains unclear, and few papers "mention, theorize or examine the potential role of contextual factors on smart city governance"[Ruhlandt, 2018, p.9]. However, the author's extensive literature review address local autonomy and local conditions as factors that appears to influence smart city governance.

Smart city governance is "argued to be influenced by many factors, most notably by the degree of autonomy or sovereignty a city possesses" [Ruhlandt, 2018, p.9]. Local autonomy is an important contextual factor as it is a foundation for local government effectiveness [Baldersheim et al., 2019]. Comparing the empirical findings with findings from a British study, which explores the opportunities and tensions in practical realization of Smart city development in British cities [Taylor Buck and While, 2017], it can be found that local authorities with limited local autonomy is less able to innovate. In contrast to municipalities in the Nordic region, the local autonomy of local authorities in Britain is low [Taylor Buck and While, 2017]. In the case study of Taylor Buck and While [2017], cities were expected to innovate within short timescales, budget cuts, and with reduced local government power and influence [Taylor Buck and While, 2017]. Hence, the study showed that local authorities with low autonomy was not properly equipped for the complex task of smart city development and innovation.

However, in the Nordic region the local autonomy of the municipalities is considered to be high [Baldersheim et al., 2019]. Digitalization is to a large extent decentralized, and at a local level, the municipalities are the leading entity for new digitalization projects [Struensee Co, 2017]. However, the empirical findings from the Nordic municipalities give mixed results in terms of the advantages and disadvantages of local autonomy for smart city development in medium-sized municipalities.

According to [Hosseini et al., 2018], smaller communities have the advantage of a less complex infrastructure and network of actors compared to large communities, enabling them to move faster with innovative efforts. The findings of this study support this statement, the Nordic municipalities have initiated and facilitated innovative smart city projects in collaboration with triple-helix actors. Especially the less formal conditions in the initiation phase of smart city development give the municipality the opportunity to initiate exploratory smart city projects without having to consider central regulations and standards. However, as discussed in the previous section, the Nordic medium-sized municipalities sometimes struggle to meet the requirements of the formal organizational setup that is required to scale projects from a piloting or exploratory phase into solutions used in daily operations.

The challenge of scaling might be related to smart city development being a complex matter which requires large technological insight and competence. In Norway, only 40% of public authorities report that they are able to collect, sort, utilize and share data about citizens [Rambøll Management Consulting AS, 2019]. Further, Kaupang [2018] found that both Norwegian municipalities and the central government see the need for more regional and national coordination on digitalizaiton. Yet, it cannot be guaranteed that centralized steering leads to better performance on smart city development. In example is the governing of digitalization more centralized in Denmark than in the other Nordic countries, with a central unit for strategic management and tactical organization. The organization sets a clear agenda which the municipalities must follow, but the organization has not been able to optimally facilitate and support municipal projects and value realization in the municipalities [Struensee Co, 2017].

Hence, there is a paradox between centralization and decentralization of smart city development. On one note, innovative solutions developed to fit to local needs might emerge from exploratory smart city projects in the less formal local context of medium-sized municipalities. Yet, with regional and national coordination and support, the municipalities can benefit from economies of scale and shared competence among the municipalities [Struensee Co, 2017]. In order to handle this paradox, close collaboration among the governmental levels and clearly defined roles are needed. In example, Statens Vegvesen [2020] suggest that the type of services provided is decided by the municipality, while the technical requirements, interfaces and formats are decided either by regional or national organizations.

In addition to local autonomy, the literature review of Ruhlandt [2018] found that local conditions might also affect smart city development. Meijer [2016] identifies two contextual variables that might impact smart city development. The variables are local knowledge potential and the nature of the problem domain. First, local knowledge potential considers the fit between new technology an the attitude of the relevant actors. Second, the nature of the problem domain considers such as democratic institutions and culture, physical environment and economic production. Further Nam and Pardo [2011] found that scarcity of resources could be an imperative for initiating smart city projects. In both FM and NM, smart city development was initiated as a consequence of poor economic conditions. The financial state of NM had been poor for many years, and they saw that they needed to change in order to improve the situation. The solution was to set ambitious goals to become a leading municipality in digitalization and smart city development. In FM, the loss of a cornerstone business forced the municipality to rethink the their strengths and properties. The solution was to use existing facilities of the cornerstone company to build the IoT campus. Hence, the case of NM and FM shows that changes in local conditions such as economic performance do impacted the attitude towards smart city development.

In addition to local autonomy and local conditions, we argue that the national approach and regulations to innovation (see section 3.5) can be considered a contextual factor which might impact the smart city development in the municipality. Regarding the approach to public innovation, Norway is considered to have a practical approach where innovative projects are initiated outside daily service delivery and municipal department budgets [KMD, 2019]. The fact that public innovation is focused towards facilitating and ensuring the success of individual projects, might be an enabling factor for smart city development in medium-sized municipalities due to their more limited budgets, and fewer opportunities to collaborate with multiple ecosystem actors [Hosseini et al., 2018]. In Denmark on the other hand, innovations are supposed to happen within the limits of daily operations with no separate budget for innovation [KMD, 2019]. The empirical findings suggest that this might inhibit smart city development as it requires the individual departments to initiate new projects in addition to their daily tasks. However, the effect of the national approach to public innovation is an area of research that needs to be further studied.

Last, an interesting finding from the case studies is that even though Norway reach the lowest scores in all the indexes examined, it is the Norwegian case-municipality which has the most organized setup and the most formal approach to smart city development. We therefore argue that contextual factors do have an impact on smart city development. An hypothesis is that the higher scores of Finland, Denmark and Sweden in the digitalization indexes might be explained by high performance in central regions, while small and medium-sized municipalities are lagging behind. However, contextual factors in Norway might be better suited for smart city development in medium-sized municipalities. These conclusions are however, based on indices and requires further research in order to be confirmed.

7 Conclusion and contributions

The Nordic countries stand out as digital front-runners in Europe as well as in a global perspective. Denmark, Finland, Norway and Sweden are all in the top-tier of many digitalization indexes. In addition, several Nordic larger cities are represented among the best performing cities in global smart city rankings. In order to map the state of smart city development in areas outside the larger cities, the aim of this article has been to map smart city development in medium-sized municipalities.

Thus, this paper has outlined the governance structure and the actors contribution to smart city development in four medium-sized Nordic municipalities. The findings suggest that the maturity of smart city development differs among medium-sized municipalities in the Nordic region. The findings suggest that, in terms of smart city governance, clear goals and strategies defined for the long term, as well as a formalized organizational setup for smart city development in the municipality is needed for smart city development to mature. In addition, support from a strategic facilitator in establishing the goals and strategies might be of importance for medium-sized municipalities to ensure a long-term focus on smart city development.

Further, the empirical findings from the case-municipalities has been placed in the context of contextual factors and country-level dynamics. The influence of local autonomy, local conditions and the countries approach to public innovation on smart city development in medium-sized municipalities has bee discussed. It was found that there is a paradox between centralization and decentralization of smart city development, and that close collaboration and clearly defined roles are needed to both get the benefits from the local autonomy of the municipalities, and the synergy effects of centralized support and facilitation. The findings further suggest that local conditions such as economic factors and scarcity of resources act as a driving force to initiate smart city development. Last, the country-level approach and regulations on innovation might influence the smart city development in the municipality. However, more research is needed on this topic.

8 Limitations and further research

Despite this study's contributions, it does contain limitations. In this section we outline some of the limitations related to our study. In terms of methodological limitations, we have interviewed one or two people responsible for smart city development or digitalization in each municipality. However, other views on the priorities for smart city development might exist in the municipality. Hence, in order to further map the state of smart city development in medium-sized municipalities an area for further research is to map the roles and interests of the leaders and employees in the municipal departments of medium-sized municipalities in order to understand how smart city development changes the organization.

Case selection based on a sample of municipalities from each country provided by domain experts. Hence, the medium-sized municipalities do not necessarily represent the most forward looking municipalities of medium-size. Hence, an area of further research is to quantitatively map the state smart city development in all medium-sized municipalities in the Nordic region.

Further, we have interviewed one case-municipality from each country as a starting point to understand the condition of smart city development in medium-sized municipalities in the Nordic countries. However, more cases should be examined in order to validate our results. Further, we have not focused on the potential of cross-country collaboration to improve municipal services. Given the quite similar characteristics of the Nordic countries, the potential of such collaboration for smart city development in municipalities is an interesting area for further research.

Last, we have discussed contextual factors and how they might influence smart city development in medium-sized municipalities in the Nordic region. However, we do not compare how contextual factors affect medium-sized municipalities compared to large municipalities. Hence, we suggest that more research is needed to further understand how contextual factors affect smart city development in small- and medium-sized municipalities compared to large municipalities.

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Appendix

A Nordic municipal interview guide

Introduction
The interviewers present themselves and the topic of the thesis. The interviewers ask the interviewees to present themselves, their role in the organization and for how long they have held the position.

A1 - Overview of projects

- How do you define smart city-development in the municipality?
- How has smart city development advanced throughout the years, to where you are today?
- Which projects are considered smart city projects?
- Why are they chosen as smart city-projects?
- How are the smart city-projects in the municipality financed?
- How does this affect the project?
- What other digitalization/ICT-projects do the municipality have?

A2 - Goals, drivers and inhibitors

- Do you have a digitalisation strategy? Does it define goals and activities for further development?
- What are the long term smart city goals of the municipality?
- What activities do you do to reach the long term goals?
- Do you have a smart city/digitalisation strategy?
- Do you look outwards for smart city-inspiration? (regionally, nationally or internationally)?
- What factors made you look to these for inspiration?
- What do you consider as the main drivers for smart city development in the municipality? Which problems can be solved?
- What inhibits smart city development in the municipality?
- Are there any general and special challenges in this municipality regarding geography, socio-economic composition, population density, etc.?

A3 - Digital infrastructure

- What is the status for digital network deployment in the municipality?
- Do the municipality have a NB-IoT or LoRa-network?
- Who is the network provider?
- In what areas are the network used?
- How can ownership of infrastructure and management in the municipality affect the choice of ICT and IoT for the municipality's infrastructure and services?

A4 - National and regional support

- To what degree does national goals and regulations influence smart city-development?
- What kind of support do the municipality get from national and regional organizations to develop your smart city-projects? (E.g. competence, financial support, change, strategic)
- How do you cooperate with the national municipal organization?

A5 - Collaboration

- How do the municipality collaborate with other actors on digitalization - development? (Business sector, Academia, Citizens, Other municipalities)
- In terms of inter-municipal collaboration: Is there coordination / collaboration between different agencies with regard to the choice of solutions?
- What cooperation opportunities can you see within the municipality for common ICT- and IoT strategies for different infrastructures, in order to achieve eg. critical mass and scale advantages?
- What cooperation opportunities can you see between municipalities for a common strategy, for example when it comes to technology development, operation and organization of service offerings?

A6 - Innovation and Ecosystems

- Do you differentiate between smart city- and innovation projects? If yes, in what way?
- Which actors do the municipality see as relevant partners for innovation?
- What obstacles does the municipality see for cooperation on innovation projects?
- Do the municipality expect that digitization will bring changes such as the purchase of external services rather than solutions run by internal resources?

A7 - Gain Realization

- What does the municipality see as the most important success criteria with digitalization? (rationalization, streamlining, better services, new business areas, etc)

Chapter 7

The municipality's role in a smart IoT-ecosystem

The municipality's role in a smart IoT-ecosystem

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Abstract
IoT is considered an enabling technology in smart city development. Despite this, there is little to no research exemplifying and analysing the use of IoT for smart city development. Thus, the purpose of this paper is to study how municipalities plan for and utilize IoT in smart city development and how they collaborate with actors in the IoT-ecosystem. Data is collected through interviews of smart city-leaders in medium-sized municipalities in Norway, supplemented with strategy documents, reports and statistics collected online. The analytical approach is a multiple case study analysis where the selected case-municipalities are analyzed and compared by using a smart city-framework adopted for IoT. The findings suggest that the aim of IoT-enabled smart city development is to lower costs and make the municipality an attractive place to live and work. It is found that utilizing IoT is not a goal in itself, but that the technology is seen as a means to reach smart city-objectives. The municipalities strives towards opening up the collected data from sensors and facilitate open innovation with local actors. However, the findings suggest that the IoT-ecosystem for collaboration is complex and difficult to navigate. This paper provides originality and value by providing practical insight into how medium-sized municipalities plan for and utilize IoT in smart city development, how different actors contribute in the IoT-ecosystem and how the municipality collaborate with the different actors.

Keywords: Smart city, Internet of Things, IoT-ecosystem, Municipality, Inter-municipal

1 Introduction

Public service organisations across the world are changing due to the ever increasing factors of urbanisation, demography and population age [European Commision, 2019]. With this in mind, Statistics Norway has performed a survey and found that Norwegian municipalities are challenged by increasingly complex tasks and service volume that put pressure on public resources - requiring them to innovate their services and implement new technology solutions to perform tasks more efficiently [SSB - Statistics Norway, 2019]. It is no longer just a matter of how fast and inexpensively a given municipal service can be produced and delivered, but rather how the municipal sector can produce more services at a higher quality with fewer resources - whilst also meeting the expectations and demands of residents and businesses [European Commision, 2019]. To better handle this situation, the concept of smart city have gained ground [Rambøll Management Consulting AS, 2019].

The goal of smart city development is to provide more efficient services to citizens by monitoring and optimizing existing infrastructure, increasing collaboration amongst different economic actors and by encouraging innovative business models in both private and public sectors [Appio et al., 2019]. In order to achieve this, smart cities rely on two things; advanced technology to gather data and human capital from collaboration with local and national actors. One of the main technologies assisting in the process of gathering data is the Internet of Things (IoT) [Velsberg, 2019]. These sensors and connected devices is intended to bring great benefits to a digital public organisation, as well as added value to its citizens [Wirtz et al., 2019]. A municipal department that is suitable for IoT and sensor monitoring is the technical sector. The main tasks within technical sector include operation and maintenance of municipal roads, as well as water and wastewater. It also include tasks in fire protection, construction case management and water - and air quality monitoring. Hence, it has been found that the technical sector is a municipal department that face great potential cost reductions and higher quality of services through introducing IoT and sensors into the services[Statistics Norway, 2019].

Despite the benefits IoT may have on smart city development, few researchers have studied how IoT are best utilized in this context. A study that have is the study of Markendahl et al. [2017], where researchers have assessed how IoT are implemented across nine public sector departments in Sweden. This study found that most of the challenges occurred because the IoT-solutions had been developed using a single firm business model. This exemplifies other similar findings regarding IoT-utilization, because it has been identified that there is a need for increased organisational strategic management and network collaboration when engaging in IoT-projects [Wirtz et al., 2019, Ghanbari et al., 2017, Falch and Maestrini, 2019]. Further, with the complex nature of IoT, collaboration becomes especially important for smaller public sector organisations due to resource constraints and geographical factors. However, most of the research regarding smart city and public sector innovation predominantly focuses on larger cities, making it more challenging for smaller cities to know what findings that also are transferable to these local communities.

This study will contribute to fill the gap of research regarding practical insight into IoT-enabled smart city initiatives in medium-sized municipalities. This will be done by performing a multiple case study analysis on four municipalities in Norway, and propose the following research questions:

How does the municipalities plan for and utilize IoT in smart city development?

How does the municipality collaborate with actors in the IoT-ecosystem?

Thus, the aim of the research questions are explore the practical implications of using IoT to innovate and transform municipal services, as well as give indications as to how the IoT-enabled smart city development may evolve in the future. To answer the research questions, qualitative data from four medium-sized municipalities in different regions has been collected. The municipalities were selected based on the presence of IoT in smart city-projects and similarities in population. Thus, it has been of interest to investigate the characteristics of municipalities engaging in IoT-enabled smart city development and the respective IoT ecosystem.

The paper is organized as follows; The second section presents relevant theory. Thirdly, insight into the Norwegian smart city context is provides. The research methods used are explained in the "Design and methods" section. Thereafter, in the "Analysis", the main findings are presented. In the "Results" section, the two research questions are discussed taking into consideration the theory and findings. In the "Discussion" section, the two research questions are discussed by considering theory and empirical findings. Lastly, the study is concluded and areas for further research is presented.

2 Theory

This section presents relevant theory to answer the research questions. First, we present literature findings related to utilization of IoT in the public sector [Mekki et al., 2019, Abualese et al., 2019, Velsberg, 2019, Wirtz et al., 2019, Guenduez et al., 2020]. Next, the smart city concept is elaborated [Wirtz et al., 2019, Ghanbari et al., 2017, Falch and Maestrini, 2019, Appio et al., 2019, Mora et al., 2019, Berntzen and Johannessen, 2016]. Lastly, the literature findings regarding two collaboration forms innovation ecosystems [Russell and Smorodinskaya, 2018] and inter-municipal collaboration [Wiberg and Limani, 2015, Helin, 2017] are presented.

2.1 IoT in the public sector

The Internet of Things (IoT) refers to the inter-connection and exchange of data among devices/sensors. It further includes the ability to aggregate, merge, analyze and process the collected data to obtain actionable information. The goal is to provide intelligent and complicated services in a multitude of areas, enabling integration of variety of end systems transparently and seamlessly [Mekki et al., 2019, Abualese et al., 2019]. Among others, IoT can be used to improve or create new public services, improve efficiency of internal management and service delivery, as well as drive collaboration with various actors [Velsberg, 2019].

IoT systems in municipalities may consist of interconnected devices and sensors distributed in houses, vehicles, streets, buildings and many other public environments to provide new services and the technical infrastructure needed to create public value through the use of data [Díaz-Díaz et al., 2017, Wirtz et al., 2019]. However, due to the dynamic nature of public services, the requirements for IoT devices can vary significantly. IoT devices that quickly and accurately can transmit information can be crucial for winter road maintenance, while speed would not be a requirement for water quality monitoring [Velsberg, 2019].

In addition, IoT brings new possibilities for citizen involvement [Guenduez et al., 2020]. Guenduez et al. [2020] states that technology and IoT can vastly improve and create a municipal environment in which involvement and participation enhances public service delivery, increase trust in government, and strengthen community factors. They further found that many citizens actually want to share their data due to personal affection, concern, and solidarity to their neighbourhood.

Utilizing IoT devices allows local governments to monitor and take immediate action on almost every aspect of urban and rural space, and provide citizens with relevant information and services. While these examples illustrate multiple potential benefits of IoT for local governments, its deployment must be carefully planned to anticipate and avoid potential difficulties. While some IoT devices require little attention, others need frequent updates, generate enormous amounts of data, as well as demand seamless mobility, real-time connections, high availability, and/or advanced security [Velsberg, 2019]. In addition, the enormous amount of data produced through the use of IoT raises concerns about data ownership, privacy and security; these aspects must be taken seriously so that neither citizens nor institutions are exposed to potential harm or wrongdoing [Velsberg, 2019].

2.2 Smart city - a fuzzy concept

The goal of smart city initiatives is to "provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration amongst different economic actors and to encourage innovative business models in both private and public sectors" [Appio et al., 2019, p.1]. In order to achieve this, technology tools such as IoT, open data analytics, sensors and connected devices has been found to be powerful [Wirtz et al., 2019, Ghanbari et al., 2017, Falch and Maestrini, 2019]. The concept of smart city has been researched for many years and has shown contrasting views and a multitude of dimensions and practical applications for the concept [Mora et al., 2019]. Thus, through an extensive literature review, Mora et al. [2019] have mapped that there are several opposites in smart city research. Thus, Mora et al. [2019] describe these opposites as four main dichotomies: techno-led or holistic, top-down or bottom-up, double or triple/quadruple helix, mono-dimensional or integrated. The opposing smart city focuses are presented in the next paragraphs.

First, smart city focus is diverging into a technology-led versus holistic perspective. The first find that smart city development is best driven by focusing on the available technology, while the other state that decision-makers also have to take the human, social, cultural, economic, and environmental factors into account [Mora et al., 2019]. What primarily separates these views is the degree to which the city focuses on citizen participation [Berntzen and Johannessen, 2016] and community building.

Secondly, there are a difference among how smart city-strategies should be formed and organized. Some strategies have a top-down approach in regards to strategy formation, where long-term vision and strategies and workgroups are formed at higher governmental management level. Whereas the bottom-up approach is more deregulated, based on self-organisation, focusing on user-driven innovation and community-led urban development. To identify what perspective a city has, one can study its strategic documents and evaluate the focus of the city in terms of citizen engagement and workgroups managing the general course of smart city development.

The third dichotomy comprises the two research streams which differ in regards to how many sectors and application areas the strategic smart city objectives cover. Researchers such as Giffinger et al. [2007] have found that smart city strategies should have a multi-dimensional approach, covering a large number of application areas and policy domains. While other researchers, like the European Commission, promotes smart city strategies that cover few application areas and municipal sectors [Mora et al., 2019].

Lastly, there is a difference in smart city research among those suggesting that collaboration should be comprised to the interaction among service providers selling their smart city solutions and the local government. However, the largest stream of research regarding collaboration are based on a triple or quadruple-helix model, where all city stakeholders are represented [Mora et al., 2019].

These opposites in smart city research show that there are multiple different perspectives to smart city development, both in theory and practice. In order to help smart city researchers better coordinate their efforts under various conditions, Mora et al. [2019] developed a smart city framework to identify the strategic principles that drive smart city development. How this framework can be adapted to an IoT-perspective and relates to the research questions is presented in section 4.3.

2.3 Innovation ecosystems and inter-municipal collaboration

To better understand collaboration structures for innovation, Russell and Smorodinskaya [2018] performed an extensive literature review. The researchers went through research regarding collaboration and ecosystem theory from the last three decades, in four different research fields to see if there were any similarities. They found that collaboration is a complex network form of interaction among businesses and other institutional actors. Such innovation ecosystems emerge at the moment when cooperating actors have achieved a certain level of integration concerned with a joint identity, joint strategy and joint goals. The development of innovation ecosystems usually rests on formal and informal communication platforms tailored to enhancing open dialogue and collaborative activities. The collaborating actors aim to co-evolve capabilities by working both cooperatively and competitively to the create better products and services [Russell and Smorodinskaya, 2018].

Most research regarding collaboration and innovation ecosystem theory surround the business sector. The role of public actors in terms of collaboration is primarily only assessed in triple helix research. There are few research articles assessing forms of collaboration among actors within public sector or inter-municipal collaboration. However, there are some Scandinavian studies that have explored inter-municipal forms of collaboration and the associated benefits [Helin, 2017, Juell-Skielse et al., 2017, Wiberg and Limani, 2015]. These studies have identified that the development of inter-municipal collaboration rests on both formal and informal voluntary collaboration structures and communication platforms. Further, it has been found that the aim is to co-evolve capabilities by working both cooperatively and competitively with other municipalities in proximity to create better public services.

As for an informal structure, Wiberg and Limani [2015] has identified the term of "consultations" and Helin [2017] similarly has identified a "Voluntary governance model". Both describe municipal cooperation as loose with no formal political guidance. Cooperation is dependent on personal relationships and they only collaborate if they see a short term benefit. This entails inter-municipal forum for the exchange of information, discussions of experiences, and launch of ideas within a wide range Wiberg and Limani [2015]. As for the more formal inter-municipal collaboration structures, both authors present two forms; Wiberg and Limani [2015] present "co-ordination" and "contracts", while Helin [2017] identify a "host municipality governance model" and a "centralized governance model". These formal inter-municipal collaboration structures regard the coordination and contractual activities in the procurement of various municipal goods and services. A characteristic is that there is a manager (often from the largest collaborating municipality in the network) coordinating the initiatives with a steering group. Both authors have found that these forms of inter-municipal collaboration allows for cheaper processes, more effective resource allocation and creation of standards that guarantee interoperability among public agencies. This in turn is expected to lead to better smart city coordination, ICT services and return on investment Helin [2017], Wiberg and Limani [2015]

3 The Norwegian Context

In order to understand why the municipalities plan for collaborate and utilize IoT in smart city development, national-wide factors of Norway needs to be clarified. Thus, this section will provide insight into how the Norwegian context of smart city development influences the case-municipalities. First, the Norwegian smart city model [Design and Architecture Norway (DOGA), the Norwegian Smart City Network, Nordic Edge, 2019, Ministry of Local Government and Modernization (KMD), 2020] is presented. Next, information regarding communication infrastructure and open data strategies [The Explorer, 2019, KMD, 2020] is presented. Lastly, findings regarding municipal collaboration [Rambøll Management Consulting AS, 2019] and public-private partnerships [KMD, 2020] are discussed.

3.1 The Norwegian Smart City model

Norway is built on values of transparency, inclusion, equality and the society model reflect these values and provides citizens with social welfare and closeness to power. Furthermore, the public sector is effective and local autonomy in public sector is high [Doga et al., 2019]. In terms of collaboration, there are long traditions for collaboration across sectors. The digital infrastructure is highly developed and digital competence among the population is high [Doga et al., 2019, KMD, 2020]. The government ensures the interests of both urban and rural areas to secure optimal utilisation of resources throughout the country[Doga et al., 2019]. These factors is what the Norwegian Smart City Network calls the 'Norwegian smart city model'. This network states that Norway, because of these factors, are provided with the necessary building blocks and platform to develop smart and sustainable solutions and services that can be scaled and exported, which in turn contributes to growth and value creation [Doga et al., 2019].

3.2 Communication infrastructure in Norway

Norway has a well-developed fourth-generation (4G) mobile network, covering almost every rural area and part of the elongated country. The country is continuously improving communication infrastructure. Thus, a priority area in the Norwegian Government plan is to deploy a nationwide 5G network by 2023 [KMD, 2020]. The aim of this is to leverage the opportunities provided by 5G networks and technology, such as Internet of Things (IoT). The IoT solutions in Norway are run on the 4G networks, but because 5G has higher speed and capacity and are able to detect weaker signals, the new network will play a significant part of the development of IoT. Increased capacity on the network is particularly important in densely populated areas [KMD, 2020].

3.3 Open data strategies

The term IoT is juxtaposed to the use of sensors. An ever increasing amount of sensors are connected to the internet. Sensors are used in everything from mobile phones and smart home solutions to devices measuring air pollution, water quality, noise levels, and so on. Meanwhile, the sensors continuously collect data that, if properly handled, can be used in predictive maintenance, decision processes and development of new business models [The Explorer, 2019].

The Norwegian government believes strongly in opening up data and runs a national registry of open data from the public sector [KMD - Norwegian Ministry of Local Government and Modernisation, 2019]. The registry contains data sets in areas such as environment, health, geography, agriculture, traffic and demographics, and the data is available to everyone. Access to such extensive open data sources makes it easier for entrepreneurs, innovators and others stakeholders to identify both problems and opportunities, as well as develop smart solutions to smarter municipalities. In the context of smart cities, for example, car-sharing companies can use traffic data and data from the Norwegian Mapping Authority to determine the potential demand for their services [The Explorer, 2019].

According to the Norwegian Government, the municipalities in Norway holds a unique position when it comes to potential cooperation on data management [KMD, 2019b, KMD, 2020]. This is because all municipalities have an overall obligation to provide the same services to their inhabitants, which also means they hold similar data sets covering the same municipal sectors and services. This provides the municipalities with the possibility to share best practice and cooperate on procurement and training measures across municipal borders. Cooperation on data, algorithms and competence in ICT and smart technology is also aimed at creating better opportunities and more synergies across sectors [KMD, 2020].

3.4 Collaboration and public-private partnerships

Collaboration among private and public actors are an important focus area for Norwegian government, and it is stated in the digital strategy for public sector 2020-2025 that "We must improve the efficiency of the public sector to leverage its resources. The public sector should not do itself what the market can do better" [KMD, 2019b, p.45]. This strategic focus is resonating with the municipalities, and a study done by Rambøll Management Consulting AS [2019] found that Norwegian municipalities view collaboration with other actors as highly important to make consistent, holistic and user-centred services. Additionally, the study found that Norwegian municipalities wish to increase the degree of collaboration with other actors across all levels of government, across public sectors and in regards to collaboration with non-public actors. However, only 19% of municipalities reported that they have a good overview of the potential partners for collaboration within their ecosystem [Rambøll Management Consulting AS, 2019]. Thus, a strategic challenge for many Norwegian municipalities is to map and understand the business ecosystems surrounding required components and services [KMD, 2019b]. This is especially important with regards to smart solutions that often are built on principals of data coordination, information sharing and re-using of information.

Further, Rambøll Management Consulting AS [2019] assessed the collaboration structures occurring within the public sector and found that many public actors refer to the quadruple helix model of collaboration. This model assumes that collaboration between public sector, private sector, academia and citizens is the most effective way to boost the pace of innovation and value co-creation in societies [Rambøll Management Consulting AS, 2019].

With regards to collaboration in procurement processes, the Norwegian government encourages public actors to make innovation partnerships [KMD, 2019b]. An innovation partnership is a procurement procedure that facilitates product and service development through cooperation between buyers and developers/suppliers. The aim is to promote innovation and use of new technologies. Innovation partnerships are used for procuring solutions that are not currently available in the market. Preliminary experiences show that startups and technology companies more easily win assignments in innovation partnerships than in other public tendering process where it is more difficult for them to know what they need to do to win the contracts [KMD, 2020].

4 Methodology

Since prior research suggests that a more detailed examination is needed to gain insight into how public organisations enable smart city development, a multiple case study analysis is chosen. As Mora et al. [2019] state, the ambiguity surrounding smart city research demonstrates that more empirical knowledge needed to understand the practical and technological implication of smart city development. A strength of case studies is the ability to deal with the full variety of evidence such as documents and interviews. Also, a case study has the potential to generate new insights that may refine and further develop current theoretical knowledge. Further, the methodology of this paper consists of selecting appropriate case-municipalities and later to collect and analyze the data [Mora et al., 2019]. Each of the steps are described in the following sections.

4.1 Case selection

In multiple case study analysis, there are three main criteria for case selection; (1) the cases should have characteristics which enables them to be viewed as one entity, (2) the cases should provide diversity across the context, (3) the cases should provide insight complexity and context of the research area in question [Stake, 2013].

In order to fulfill the first criteria of Stake [2013], all selected municipalities chosen had to have initiated at least one smart city-project enabled by IoT. Initially, the sector in which the smart city-project was implemented was not of importance prior to the interviews. During the interviews, the technical sector was chosen for further exploration as the municipalities recognized IoT-projects in this sector as low-hanging fruits and that IoT could be utilized for efficiency and cost reduction.

Another unifying criteria of municipal size was used. These municipalities should be of medium size ($\sim$ 20.000 to 60.000 inhabitants). Medium-sized municipalities was chosen because Norway consists of mostly small and medium-sized municipalities. The size interval is set to include case-municipalities which are large enough to have initiated their own IoT-projects, but small enough to have different demographic, social and economic characteristics than larger cities. Also, with the complex nature of IoT, collaboration becomes especially important for smaller municipalities due to resource constraints and geographical factors. Additionally, most of the smart city-research focuses on larger cities, leaving room for more research on medium-sized and small municipalities.

Next, in order to provide diversity across context, the municipalities should be situated in different regions. It was also important that the selected cases reflected both the northern and southern parts of Norway. Hence, we are able to map how smart city development is enabled through IoT-use in medium-sized municipalities in different county and regional contexts. Further, the case-municipalities are independent of each other, meaning that we have not detected any inter-relations among them.

Lastly, in order to provide insight of the complexity and context of IoT-enabled smart city development, one selection criteria were considered. The municipalities should be in a sample of promising municipalities for smart city development, identified by domain experts.

4.2 Data collection

Information about the four municipalities were first collected through websites, reports and articles that were available online. Thus, we had knowledge about several areas of the smart city development in the selected cases before the interviews were held. Next, a one hour semi-structured interview were conducted with a smart city manager in each of the municipalities. The interview template can be found in appendix A. Based on the template, the same general open-ended questions were asked in all of the interviews and minor adjustments to the questions were done during the interviews in order to best make it relevant for for each case. The interviews were conducted in the period March to April 2020. For two of the case-municipalities our interviews supplement previous interviews, conducted in 2019 by the connectivity company Telenor. Also, all municipalities received an e-mail with follow up questions to be answered by the interview object in order to supplement the analysis. Three out of four digitalization managers responded to this email. Table 1 gives an overview of the type of data collected, as well as the related informants and authors.

Further, the context in which the cases appear influences the choices made and the activities initiated within each case [Stake, 2013]. Therefor, in addition to the semi-structured interviews, secondary data about national influences has been collected. This includes national digitalization strategies and different reports on the state of smart city development and digitalization in Norway. Table 1 gives an overview of the type of data collected,as well as the related informants and authors.

Table 1: Overview of data

Data format	**Description**	**Sources**
Interviews	4 interviews with 4 informants from 4 municipalities	Digitalization and smart city leaders
Documents	Municipal strategies and documents regarding smart city National digitalization and smart city reports and strategies	National government, DOGA, Rambøll
Statistical data	Municipal statistics	Statistics Norway
Online resources	The municipalities own web pages, project documents, strategies and reports	The municipalities

4.3 Data analysis

For the data analysis of this paper, an analytical framework has been used. The framework is closely connected to the framework of Mora et al. [2019] presented in section 2.2, but has been adapted to an IoT-perspective. The analysis is done in two steps, the first step identify how the municipality plan for and utilize IoT for smart city development, while the second step maps how the municipalities collaborate with actors in the IoT-ecosystem. These steps also make it possible to map the strategic focus of IoT-enabled smart city development in the case-municipalities. An overview of the analytical framework is shown in table 2. The subsequent paragraphs explain the two steps in further detail.

Table 2: Analytical framework for IoT-enabled smart city development.

Analytical framework steps	**Dimensions**	**Smart city focus**
Step 1: *Identifying important activities undertaken by the case-municipalities*	Community building, Strategies and workgroups, Services and Applications, Digital infrastructure	(1) Technology-led or holistic
	Community building, Strategies and workgroups, Services and Applications, Digital infrastructure	(2) Top-down or bottom-up approach
	Services and Applications	(3) objectives has few application areas or crosses multiple application areas
Step 2: *Identifying important actors in the IoT-ecosystem*	Private firms, academia, regional public actors, citizens, other municipalities, civil organisations	(4) Double or quadruple-helix model of collaboration

The first analytical step is to code the empirical findings into four dimensions to identify how the case-municipalities plan for and utilize IoT in smart city development. The first dimension regards community building activities supporting the construction of an open and inclusive collaborative environment able to support the implementation of IoT-projects. This entails activities stimulating citizen engagement and digital competence, user-driven innovation and community-led urban development, as well as activities informing the city's stakeholders. The second dimension, strategies and workgroups, identify the activities aiming to guide and develop smart city development. Examples of activities includes action plans and road maps, assessment methods and workgroups. The third dimension maps the municipality's IoT-projects in technical departments. Last, activities aiming to develop the necessary digital infrastructure for IoT is identified.

To describe how the municipality collaborate with the actors in the IoT-ecosystem, the second step of the analytical framework identifies the different actors and their role. In order to do this, empirical findings is coded into dimension groups of different types of actors. The actors include private actors, academia, citizens and public actors.

Through use of the findings from step one and two, the last part of the analysis outlines a broader perspective of the municipalities' smart city focus, as well as how IoT-enabled smart city development may evolve in the future.

4.4 Case descriptions

Municipality M1

There lives approximately 30.000 people in M1 and the municipality is located close proximity to an urban region. The municipality is an important regional center for neighboring municipalities and has a long history of organizing cooperation with and among them. M1 is a significant industrial and agricultural municipality, making the city center an important meeting place for trade and services within the region. Two institutions of higher education is stationed in the municipality and they focus on having a broad educational offer - especially within technology. The municipality has a smart city strategy, but does not have an IoT-strategy for smart city development. Further, it is found that the municipality have tested or developed solutions within; smart buildings, smart infrastructure, smart mobility and transport, smart welfare technology and smart learning.

Municipality M2

M2 has approximately 60.000 inhabitants and is categorized as a somewhat urbanized region. They do not have their own university or higher school or education, but views academia as an important actor collaborating with the local high schools to create technology interest. The municipality has a smart city strategy, but does not have an IoT-strategy for smart city development. The municipality is utilizing IoT and have developed an e-government mobile app for citizen participation and information sharing.

Municipality M3

There lives approximately 50.000 people in M3. M3 is the largest municipality in its rural region. Therefore, the municipality is as an important regional center for neighboring municipalities. M3 has evolved to become a significant trade, education and communication center. The municipality has a relatively modest industry and it is characterized by small and medium-sized enterprises within metal and machinery-industries and food industries. The municipality does not have an IoT-strategy, but it has a smart city strategy. On their website it is stated that they have many different initiatives/projects to help make the municipality smarter. The projects range from the introduction of welfare technology in the elderly care to driver-less vehicles in the city center.

Municipality M4

The number of inhabitants in M4 is approximately 30.000. The municipality is categorized as a somewhat urbanized region. The most important industry players in the municipality are engineering, wood processing and pharmaceutical industries. The municipality does not have an IoT-strategy, but have a smart city strategy. To reach smart city goals, M4 have initiated a Smart City-program to stimulate experimentation, testing and demonstration of new technology, new services for citizens and new types of business models to create value for a more forward-looking society. Currently, the municipality has multiple ongoing smart city-projects.

5 Analysis

The analysis is done in two steps. The first analytical step categorizes the empirical findings into the dimensions community building, strategies and workgroups, services and applications and digital infrastructure to identify how the case-municipalities plan for and utilize IoT in smart city development. The second step maps how the municipalities collaborate with actors in the IoT-ecosystem. After performing step one and step two, the last part of the analysis outlines a broader perspective on the municipalities' smart city focus, as well as how IoT-enabled smart city development may evolve in the future.

5.1 Step 1: Identifying important activities

Community building
This first dimension of the analytical framework regards community building. This is defined as activities supporting the construction of an open and inclusive collaborative environment able to support the implementation of IoT-projects. These activities includes stimulating citizen engagement and digital competence, user-driven innovation and community-led urban development, as well as activities informing the municipality's stakeholders. Hence, the identified community building activities in each of the case-municipalities are outlined in this section.

First, the interviews showed that all municipalities focuses on increasing citizen engagement and digital competency to support the smart city development. M1 report that they early on educate important end-users on the value of IoT and application-area of the sensors in regards to privacy and safety measures. This is done to avoid misunderstandings and to make implementation at a later stage easier. M1 also report to engaging the local university in innovative project to increase digital competence and engagement. M2 focuses on involving high-school students and educating them to increase competence and citizen engagement in the local society. M2 also stated that by first focusing on smart city-projects easily noticed by the citizens, the municipality gain citizen engagement and aim to more easily implement more technology-heavy projects at a later stage. In addition, M2, M3 and M4 have established physical areas such as smart streets, city labs and a Smart bench, to showcase smart city technology (sensors, connected devices and IoT) and create engagement around the IoT-enabled smart city development.

In order to fit IoT-projects to citizen needs, all municipalities is found to focus on user-driven innovation and community-led urban development. To stimulate user-centred services, all case-municipalities map citizen-needs in different ways. M1 report to gain insight directly from citizens through workshops, panel talks and surveys. M2 also have a citizen panel and push out surveys through the municipalities own mobile app. In this app, citizens provide information both directly and indirectly. M4 map citizen needs through surveys and communication on social media. Furthermore, the interviews identified three activities performed by M3 that aim to stimulating community-led urban development. M3 is in the process of establishing a city lab where one of the main goals is to engage the municipality's citizens by making them initiators of new smart projects. Additionally, the municipality try to stimulate increased quality of private efforts by both opening up municipal data and allowing sensor testing through municipal sensors. Next, M3 arrange market dialog forums with potential technology providers to gain input and substantiate potential synergies for new projects.

Lastly, the interviews showed that M3 in particular engage in activities that aim to improve information flow to the local businesses for increased local growth and community building. As previously mentioned, M3 arrange market dialog forums with the potential technology providers to inform about the status of digital development in the municipality. These forums are also a forum where the businesses are able to influence future smart city-projects and regulations, to some extent.

Strategies and workgroups

The strategies and workgroups dimension of the analytical framework is to identify activities that provide plans, evaluation methods and strategically guide smart city development. None of the case-municipalities have strategies or workgroups exclusively for IoT, but works towards smart city development in a coherent manner. The identified activities in each of the case-municipalities are outlined in the next paragraphs.

In terms of action plans and goals providing strategic direction to IoT-enabled smart city development, all municipalities show similar results in regards to smart city goals. All four municipalities aim to select projects that provide citizens with better quality municipal services at a lower cost and more jobs for inhabitants through new business opportunities. Furthermore, findings suggest that none of the municipalities view IoT-use as a goal in itself, but they see IoT as means to reach smart city-objectives in general. In terms of sharing data, both M1 and M3 report to having an open data strategy aiming to collect all municipal data in an API to make it easier to utilize, as well as to stimulate innovation and provide entrepreneurs and local businesses with potential business opportunities.

Secondly, the municipalities also show similarities in how they evaluation IoT-projects. All municipalities report that they use the national project management tool for innovation and digital projects, called "Prosjektveiviseren", but the municipalities are to a varying degrees active users. M1 states that they use the project management tool daily, especially during the selection and evaluation phase. During the selection phase, the municipality works systematically with project selection and has a management document that helps them choose the right project in the smart city initiative. This is done by the municipality emphasizing five main categories, which give each idea a score of 1-3 within each category and where the project idea with the highest weighted total score are chosen. M2 on the other hand, has just recently begun using this management guidance tool. Lastly, municipality M4 has previously been using the evacuation tool, but finds it too narrow for their smart city needs and are in the process of making their own system for project selection, execution and evaluation. They hope that their system can collect all process phases in one system and make it more easy to manage and gain experience from. M4 also have a goal of other municipalities using their system in the future to more easily share and transfer experiences and solutions.

Lastly, all the municipalities have some sort of workgroup assigned to managing the strategic course of smart city development. The structure of M1 and M2's workgroup have some similar characteristics where a separated workgroup assist sectors and facilitate smart city initiatives across the municipal departments. M3, on the other hand, report that every smart city project is unique and that the structure of the workgroups vary with the different smart city-initiatives. In example, M3 have in some projects included external actors into the municipal project group to secure proper resource allocation. M3 also report to arranging meetings where representatives from all municipal sector departments can present smart city-project ideas or provide insight to substantiate synergies within the municipality. In M4 there is one leader ensuring the course of smart city development, but the leader have various smart city representatives in the different municipal departments. These representatives have smart city development as an additional focus area to their everyday sector-defined tasks. This structure was chosen because of its resource effectiveness and to secure that the needs of the different departments is taken into account.

Services and applications

The services and applications maps the municipality's ongoing and planned IoT-projects in technical sector. An overview of the projects is outlined in table 4. Lastly, some of the projects are presented to provide practical insights on project implementation as well as the municipalities' experiences and challenges.

First and foremost, the findings from the interviews showed that the municipalities have initiated several IoT-projects in multiple municipal sectors. When the smart city leaders in the municipalities were asked about in which areas the municipality had come the farthest in terms of smartness, all answered the health sector. Yet, when asked about which municipal department they found to hold the most profit-gaining potential, all municipalities answered the technical sector. With this question, they did not chose the health sector because the interviewee viewed this sector as the most challenging to make more efficient with IoT-use and sensor technology because of the privacy requirements and personal data management. However, with technical sector they found that the services provided suits IoT and sensor monitoring well. Therefore, it was decided to further focus on the IoT-projects initiated within the technical sector. To outline the identified application areas of IoT in technical sector, table 3 provide practical insights into how IoT have been utilized in technical sector activities.

Table 3: Application areas of IoT in technical sector.

Area of application	**Description**
Air quality	Sensors monitor air pollution for proactive operations and improved control
Water and wastewater management	Sensors monitor water quality and consumption for proactive operations and improved control
Water temperature	Sensors continuously register swimming temperatures
Waste management	Sensors register fill-levels for proactive operations and improved control
Street lights	Sensors register human activity for smarter light control
Mobility and transport	Sensors for autonomous driving, to monitor service cars and parking spaces
Winter road maintenance	Sensors monitor snow levels and temperature to improve and optimize snow clearing
Facility management	Sensors register occupancy for light optimization, suggest system maintenance needs and improve overall buildings control
Web -or mobile application for citizens	Digital platform presenting sensor data, such as water temperature and snow levels for citizens

Implementation of IoT in the different application areas presented in table 3 have reached different levels of maturity in the different case-municipalities. Some projects are at a planning stage, while other are small-scale innovative pilots with few included actors. Some projects on the other hand, are large-scale pilots that involves multiple actors and business cases. Last, some of the municipalities have IoT-projects within the technical sector that are in operations, meaning that the project is fully implemented and finalized. Table 4 categorizes the identified IoT-projects of each municipality.

Table 4: Type of IoT-projects in technical sector.

Area of application	**M1**	**M2**	**M3**	**M4**
Air quality	Pilot x 2	No project	Pilot	Pilot
Water temperature	No project	Pilot	No project	No project
Water and wastewater management	Pilot	Planned	Pilot	Pilot
Waste management	No project	No project	No project	Operations
Street lights	No project	Planned	No project	No project
Mobility and transport	No project	Planned	Large-scale pilot	Operations
Winter road maintenance	Large-scale pilot	Planned	No project	Pilot/Op.
Buildings management	Operations	No project	No project	Operations
Fire safety	No project	No project	Large-scale pilot	No project
Web -or mobile application for citizens	No project	Operations	No project	Planned

Planned: areas where pilot project or large-scale pilot are planned started.
Pilot: small scale innovative project with few involved actors.
Large-scale pilot: large scale innovative project involving multiple actors and business cases.
Operations: The project is fully implemented and finalized.

Table 4 shows that every municipality has at least one project in operation or as large-scale pilot in technical sector. M3 has planned projects within four technical departments. M4 has come the farthest when it comes to the number of operational projects. The interviews gave some indications as to why there are so many IoT pilots and much fewer operating projects. In example, M1 stated that scaling projects from pilot-phase to full scale often becomes an issue. The group leading a successful pilot is often a small group of motivated people, but the sector that is going to use the solution in full-scale usually needed much more motivation and training. It is often difficult to get the users to change their processes. M2 find that scaling projects also, often are limited by the technology and its low degree of maturity.

Last year, M2 initiated a pilot project to measure water temperatures. Unexpectedly, the sensors have not withstood the winter and all sensors have been damaged and must be replaced this year to continue the project. The municipality experiences being used as test rabbits for unexplored sensor technology. M2 further says that there are many entrepreneurs and smaller companies that make sensors, but that few have managed to scale up production. Therefore, it is also a challenge to find sensors of sufficient quality. M1 have experienced a similar experience with air quality monitoring. First, the private partner that were providing the IoT-solution took too long to decide on the sensor type. This was because the actor struggled to find collaborating partners in the complex network of private actors. Furthermore, when the sensors were to be installed, the supplier failed to complete the task and had to get another external player come to get the sensors installed. M1 have also experienced that they are promised sensors for similar projects that do not measure what they initially were presented to do, so that the municipality still had to check the monitors with personnel. Thus, the IoT project did not provide the municipality with the benefits of time- and cost-reductions that it initially were planned to give.

Furthermore, both M1 and M4 have initiated IoT-projects in winter road maintenance. M1 participates in a large-scale pilot with surrounding municipalities of smaller size. The goal of the project is to use smart technology to ensure more efficient planning, coordination and more accurate information, since winter road maintenance previously have been based upon employee experience and citizen input regarding snow levels. The project is an innovation partnership. Hence, the most ideal solution is not defined, but the problem is designed to motivate competition between suppliers while providing the municipalities with multiple solutions to choose from. Case-municipality M4 have also started a pilot project where they have deployed sensors in four places in the area to measure if it has snowed and the temperature around the snow. In this project, the smart city manager report that he himself sees more value of the IoT-project than the department that are going to utilize the data. It has therefore been challenging to scale up the project further.

Digital infrastructure

Digital infrastructure refers to the degree to which the municipality have the technological infrastructure necessary to utilize and benefit from IoT-technology. Examples of such infrastructures are LPWAN-technologies. This subsection present the findings of the state of digital infrastructure in each municipality. The findings give indications on how the municipalities go about choosing network and smart technologies, as well as how they facilitate open data and data platforms.

All municipalities is found to use a LoRa- or NB-IoT network to push sensor data through. M1 and M2 uses a LoRa-network provided by external partners. M2 report that they chose the LoRa-network as its implementation had proved successful in another municipality of larger size. Hence, other LPWAN-technologies were not considered as an option. M1 on the other hand, also utilizes the NB-IoT network for a project in its pilot phase. Municipality M3 makes a point out of being independent of technology network and are open to use both LoRa and NB-IoT in order to acquire the right technology. Municipality M4 only uses the NB-IoT network to push sensor data through, but experiences challenges with mobile network deployment related to geographical factors.

Next, the analysis have identified how the municipalities facilitate open data and data sharing. In M1, the smart city workgroup secure requirements on new data systems to support open API's. As for municipality M3, they focus heavily on data sharing and are working on creating an open data platform. M3 states that all kinds of data is important, and whether it is historical or sensor data is not important for them. Another finding, reported by M3 and M4, was the lack of standardized data formats and common data platforms. However, a challenge reported by all municipalities is that the business models for IoT-use and data handling is undefined and difficult to lay out.

5.2 Step 2: Identifying the actors in the IoT-ecosystem

To describe how the municipality collaborate with the actors in the IoT-ecosystem, the second step of the analytical framework identifies the different actors and their role. The actors include multiple types of private actors, academic actors, citizens and inter-municipal collaboration. The municipalities collaborate with many actors, both public and private ones. Yet, an interesting finding from the interviews is that all the municipalities mention that the IoT-ecosystem of actors is complex and difficult to keep track of. Table 5 outline the findings of the identified types of actors and their contribution on IoT-projects in technical sector. The list is based on the interviews and are not necessarily complete. The next sections further elaborate on the role of the different actors and how the municipality collaborate with the actors.

Table 5: Overview of the participating actors in the IoT-ecosystems of the municipalities.

Actor	**M1**	**M2**	**M3**	**M4**
Private actor	Local company - Network, National company - Platform, National company - Network,	National company - Platform National company - Partner network	Local company - Tech & Automation Local company - Network National company - Platform, Network	Local company - Technology National company - Platform, Network
Academia	University - Research, University - Student project	High school	University - Research, University - Student project	University - Research, University - Student project
Citizens	Direct - Survey, Direct - Workshop	Direct - Survey, Direct - User Panel	Direct - City lab	Direct - Survey, Social media, City lab
Public actors	Municipality	Municipality, Local public company - Connectivity	Municipality, Regional public company	Municipality

National private actor: large companies spanning across Norway that offer the municipality with comprehensive solutions, such as platform or connectivity companies

Local private company: small and specialized private company stationed within the municipality

Private actors
As shown in table 6, all municipalities collaborate with private actors, both local and national companies. The role of the private actors was found to first and foremost to provide technology solutions and new services. Sometimes the private actors were also used as pure process consultants, to map needs, and for method and service design. Furthermore, it was reported that M2 considered it as important to share vision with the companies in a project context. This was because M2 deemed it easier to achieve the goals of the project and scale up the service solutions in later project phases.

In addition, it was found that the number of relevant actors in regards to IoT is large and that it is in many cases difficult to know what providers to collaborate with or to find companies delivering full IoT-systems. Furthermore, the private actors collaborated with the municipalities can be characterized to being small and operating in niche markets. Hence, the municipalities reported to it sometimes being difficult to scale the technology solution to the required level of service. The municipalities also stated that it is a problem that the IoT-technology is immature, which made it more difficult for the private actors to customize systems and technology to local municipal needs. In addition, the municipalities stated that most of the private actors are still in the exploring phase of figuring out the potential application areas of IoT leading to the decision-makers feeling like test subjects. Furthermore, the municipalities report that they sometimes experience that companies are less willing to share data and support open API's. M3 reported to saying that many private actors often have a preference towards certain technologies, which can pose as a challenge when agreeing on the best technology for the needs of the municipality.

Academic actors
All the case-municipalities collaborate with academic actors to some extent. It was found that the academic actors have a clear desire to get research funded and to be provided with exciting topics for further research. M1, M3 and M4 are in an unique positions, situated in close proximity to universities aiding them through research and development in IoT-projects. The municipalities wish to provide the academic actors with assignments, and sees it as an activity that, in the long term, provide the municipalities with a highly digitally competent academic institutions. Nevertheless, a challenge regarding research is for instant value creation in the municipalities is the exploratory nature of research. Research processes might take years, while the municipalities request that IoT-projects show results which meet the municipality's needs in a shorter time frame.

Further, M1, M2, and M3 see the importance of collaborating with academic institutions to increase competence in the local community through facilitating relevant projects for students. Engaging younger people in IoT-projects is also seen as important in M2. The municipality is not closely situated to a university, but invite high school students to participate in smart city development and IoT-projects to motivate and engage at a young stage.

Citizens
All the municipalities are focusing on involving citizens into smart city development. M2, M3 and M4 have IoT-projects where the main goal is to showcase IoT-technology. The main goal of these projects is to educate and engage the citizens on the potential of IoT in public services.

However, citizens are also participating through identifying needs for the municipalities and test smart city solutions. M1 report to gain insight directly by the citizens through workshops, panel talks and surveys. M2 also have a citizen panel and push out surveys through the municipalities own mobile app. In this app, citizens provide information both directly and indirectly. M3 is in the process of establishing a city lab where one of the main goals is to engage the municipality's citizens by making them initiators of new smart projects. M4 has also recently opened a City Lab. These facilities are supposed to be overall organizations for smart city development, but also an arena for citizens to participate in smart city development. Further, M4 gain insight from citizens through surveys and communication on social media. In addition, M1 also dives into the customer journeys of their services to find out how everyday problems present them self in practice for an individual citizen. Overall, the case-municipalities state that it is crucial to map user-needs to increase quality of municipal services and provide better and smarter solutions.

Inter-municipal collaboration
While collaborating with the above mentioned actors fit the quadruple-helix model of innovation [Hasche et al., 2019], the findings suggests another important form of collaboration for the case-municipalities – namely inter-municipal collaboration. This form of collaboration was present in every case-municipality. Inter-municipal collaboration provides advantages in terms of exchange of experiences, due to the complexity of the IoT-ecosystem and difficulties when it comes to identifying credible suppliers [Markendahl and Deij, 2018, Markendahl and Deij, 2019]. Hence, through inter-municipal collaboration, municipalities can share experiences with each other to ensure quality of collaboration with other actors in the IoT-ecosystem [Markendahl and Deij, 2018]. M1 stated that the importance of inter-municipal collaboration could also be regional, in the way that all the municipalities in the same county joined forces in projects spanning across them to gain more power towards regional government structure. The types of inter-municipal collaboration is presented in table 6.

Table 6: Identified forms of inter-municipal collaboration

Inter-municipal collaboration	**Informal/ Formal**	**Characteristics**	**Examples**
Knowledge community	Informal	Exchange of relevant experiences. No sharing of people or resources	M1/M2/M3/M4; Contact is established via conferences, meetings and network M1; Member on online community where municipalities chat and share experiences
Transferring solutions	Informal	Implementation of existing solutions developed by another municipality	M1/M2; Has adopted a bigger municipality's network-solution due to the its success M3; Make a point out of creating solutions to be transferred to other municipalities
Project based	Formal	Joint project where all involved parties invest resources, resulting in a product or service to be used by all parties	M1; IoT-project with three neighbouring municipalities for winter road maintenance M2; IoT-project to integrate neighbouring in a common IoT-platform M4; IoT-project with two neighbouring municipalities

The first form of inter-municipal collaboration identified is the knowledge community. One form of knowledge communities are knowledge exchanges through meetings and online communities. In example, knowledge exchange between municipalities is done through one-on-one meetings or conferences where representatives from multiple municipalities share their experiences to learn from IoT-projects in other municipalities. In online knowledge communities, multiple municipalities are represented. An online community for smart city development is in example an informal chat group where smart city leaders from multiple municipalities are participating. In a knowledge community, the municipalities does not share people or financial resources among one another. However, the knowledge communities enable the municipalities to ask questions and dynamically share their latest IoT-achievements and smart city development achievements. Overall, all the case-municipalities participate in some type of knowledge communities.

Transferring of solutions among municipalities, refers to implementation of IoT-solutions which have been developed by other municipalities. All the case-municipalities is found to transfer their own or another municipality's solutions. This form of exchange is seen as an important activity to exchange technological experiences, limit duplicate solutions and save municipal resources. The municipalities also engage in this form of collaboration to easily implement pilots to showcase to their citizens that smart city-initiatives work and to create citizen engagement. An identified challenge with this form of inter-municipal collaboration is that the solutions do not always work as expected or do not fit the municipal needs. M2, in example, have experienced that a solution was not as thoroughly developed as it was promised. This lead to the solution not being implemented in M2, but the municipality used resources that could have been better utilized elsewhere.

The last identified form of inter-municipal collaboration, is project based inter-municipal collaboration. This is a more formally structured collaboration form with a specially assigned project management group with representatives from all municipalities. The nature of cooperation is limited to joint collaboration defined from project to projects. The participating municipalities invest both financial resources and people into a joint IoT-project which results in a product or service to be used by all involved parties.

Both M1 and M4 have IoT-projects where multiple municipalities participate. First, M4 has collaborated with two neighbouring municipalities on an IoT project. In addition to this project, the municipality is in the process of integrating it's IT-architecture with surrounding municipalities. M1 on the other hand collaborates with neighbour municipalities of same size on an a large-scale IoT-pilot to improve winter road maintenance. In general M1 report that they often collaborate with smaller, surrounding municipalities. In these inter-municipal collaboration with smaller municipalities, M1 is the biggest actor and acts as a centralized governing actor. However, for the winter road maintenance project, M1 experiences that resource investments are more similar among the municipalities compared to collaboration with smaller municipalities, but at the cost of higher degree of compromising and longer decision-making processes to ensure that all municipalities local interest are secured.

5.3 Mapping the municipal smart city focus

Up until now, the analysis has focused on the individual activities undertaken by the municipality to plan for and utilize IoT, and collaborate with actors in the IoT-ecosystem. This part of the analysis aim to outline a broader perspective of the municipalities' smart city focus, as well as how IoT-enabled smart city development may evolve in the future. Table 7 below and the following paragraphs present the findings.

Table 7: Smart city focus findings from analysis

Smart city focus		**M1**	**M2**	**M3**	**M4**
1. The strategy is:	Holistic				
	Technology-led				
2. The strategy development approach is:	Top-down				
	Bottom-up				
3. The strategic objectives:	Cross multiple application areas				
	Has few application areas				
4. The structure of collab. network is:	Triple helix				
	Quadruple helix				

Table 7 show that the smart city focus among the case-municipalities are of similar nature. First, the empirical findings indicates that all the municipalities have a holistic smart city strategy. Meaning that the municipalities are influenced and driven by both technological advancements and multiple softer sides of smart city development, such as human, social and economic factors[Appio et al., 2019]. Human and social factors include making the municipality an attractive place to live and work, as well as a focus towards citizen participation and digital competence. In terms of economic factors, some of the IoT-projects in the municipality are found to be driven by goals to improve efficiency or reduce costs. In total, it is found that the municipalities primarily see IoT as a means to reach smart city-objectives, rather than IoT-implementation being a goal in itself. The most important factor for the municipalities is how IoT-technology can meet citizen needs; the municipalities want to fit smart technology to their needs rather than designing their services to fit the technology. Hence, all municipalities show a holistic view on utilizing IoT in smart city development.

In terms of the municipalities strategy development approach, all municipalities balance top-down and bottom-up approaches. First, the empirical findings suggest that the municipal government is displaying a top-down approach, through defining the long-term vision and strategic documents for supporting smart city development. On the other hand, it is found that much of remaining decision-making processes is deregulated and that the smart city workgroups are able to self-organize efforts to take action if required. Furthermore, the municipalities engage in forums, conferences, workshops and meetings regarding smart city development in order to generate interest, stimulate collaboration with new actors and raise public awareness to IoT and smart city. These are examples of the municipality overall having a community driven focus and a bottom-up approach. In addition, every municipality have a workgroup of employees working towards smart city development daily. The workgroups are to a varying degree composed with consideration to sectorial expertise. M3 report to taking sectorial competence into consideration in decision-making processes and M4 states that the smart city workgroup consists of several sectorial experts that make sure that sectorial requirements and needs are taken into account in IoT-projects. Another interesting finding in regards to the municipalities bottom-up approach, is that all municipalities have initiated or begun planning efforts to make public data freely accessible for local developers interested in building new digital services. Thus, the findings show that the municipal governments provides leadership and regulation while ensuring that smart city development has a decentralized development process in place that foster open, inclusive and cohesive collaboration. Hence, the analysis indicates that the municipalities balance a top-down and bottom-up approach for IoT-enabled smart city planning and facilitation.

Next, the data obtained from the analysis of services and applications indicate that the municipalities strategic objectives cross multiple application areas. In example, M1 use IoT in water monitoring in technical sector, and aims towards making adjustments to the solution so that sensors can notify health care professionals. However, this is only seen as a future possibility because it requires integration of several data sources, more strategical planning in terms of data security, as well as organizational change. In addition, M2 is operating a mobile application for citizens that provide them with information regarding public services in both technical sector and other departments in the municipality. For internal use, M4 has developed a project management tool that will be utilized for smart city-projects across sectors and application areas. This is also elaborated upon by M3, which state that they first gain proper value from IoT, once they see multiple application areas across sectors. Hence, the municipalities show a strategic smart city objective crossing multiple application areas.

Lastly, the data describing municipal collaboration with actors show that the municipalities strive towards a quadruple helix model of collaboration where private and public actors, academia and citizens collaborate to create better municipal services. Most of the smart city projects engage private actors, contributing with competence and resources. The institutions for education and research takes a smaller role than private actors, but they are important resources in terms of R&D and future digital competence. Further, the analysis show that the municipalities make an effort to strengthen citizen participation. In example, this is done by increasing the citizens active involvement in the development process of IoT-projects aiming to innovate and improve municipal services. All in all, the collaborative findings provides evidence that the municipalities move towards a quadruple helix model of collaboration.

This analysis shows that all case-municipalities in general have an holistic smart city strategy with multiple objectives, that they balance the top-down and bottom-up development approach and that they move towards a quadruple helix model of collaboration. These smart city focuses correspond with what Mora et al. [2019] have found as best-practice characteristics in leading European smart cities of larger size, such as Amsterdam, Barcelona, Helsinki, Vienna. Hence, these findings suggest that IoT-enabled smart city development in the case-municipalities are headed in a positive direction and that the future is bright in terms of continual development.

6 Discussion

The aim of this paper is to identify how municipalities plan for and utilize IoT in smart city development, as well as how the municipality collaborate with actors in the IoT-ecosystem. This section aim to extend these perspectives by relating empirical findings to previous literature. The next sections will therefore point out the practical implications of utilizing IoT to innovate and transform public services by discussing how IoT-projects are managed, how municipalities collaborate with private actors and academia, the importance of citizen participation and the synergy effects of inter-municipal collaboration in smart city development.

6.1 Managing IoT smartness

From a management perspective, implementation of IoT in the public sector context is intended to increase public resource efficiency, transparency, collaboration, as well as the effectiveness of public services [Wirtz et al., 2019, Velsberg, 2019]. Thus, the primary objective of IoT is to create public value. However, Velsberg [2019] has found that management capabilities and robust technology strategies are required to realise the smartness value in the public sector. This section aim to discuss the topic of managing IoT smartness and to evaluate how IoT implementation may influence smart municipal development in an administrative perspective.

According to Velsberg [2019], the realisation of IoT smartness in public sector requires management capabilities and strategies governing development. In this paper it was found that all case-municipalities has a management team and a strategy guiding smart city development. Most of the municipalities mentioned that the choice to implement IoT was a strategic choice. In addition, the interviewees appreciated that IoT quickly allowed them to gain insight into valuable information that previously required a lot of resources. In example, the municipalities are now able to place sensors in public spaces to measure water temperature, air quality and efficiency of waste management. They found that simple sensor measurements have made it possible to make simple estimates on potential savings, which has made decision-making and resource allocation easier. The benefit of quick IoT-testing is also valued by Guenduez et al. [2020], which states that "the great advantage of this data type is that it represents real-time information, generating minimal costs. It provides a new basis for government and administrative decisions: simple, needs-based, and cost-effective regulation and control can be achieved".[Guenduez et al., 2020, p.194].

Further, the literature is not clear in regards to whether or not public sector organisations should have a specific IoT strategy for smart city development [Velsberg, 2019]. However, it is found that some cities and municipalities adopt their practices more to the new technology, whilst other more focuses on the technology being a substitute to already working practices [Guenduez et al., 2020, Mora et al., 2019]. Mora et al. [2019] believes that the different technologies are less relevant than the service itself. This fits with the findings from the four case-municipalities where none of them have a specific IoT-strategy. They wish to be technology-independent and that they can chose the technology that best fit each project at different times. M3 stated that their municipality only needs an IoT strategy when their sensors provide them with added value beyond the primary needs of the initial sensor placement. However, some researcher stress the importance of having a plan for IoT-implementation and that the municipal organisation have to be aware of the needs of the technological components [Guenduez et al., 2020] and how the technology shapes the local environment and collaboration [Velsberg, 2019]. Hence, as the findings suggest, public sector organisations and the case-municipalities can benefit from having a strategic plan for IoT implementation and management.

Next, Guenduez et al. [2020] have found that IoT-enabled smart city initiatives place high demands on public decision makers. The initiatives require technical, organisational, and managerial skills, because decision-makers have to understand and control the new technologies [Guenduez et al., 2020]. They are also responsible for successful implementation and to secure added value to citizens [KMD, 2020, KMD, 2019b]. This challenge becomes especially apparent in the procurement phase of the projects. M3 explained how municipalities through a normal technological procurement procedure make a public tender with all project requirements thoroughly specified. With IoT the municipality have to use the method for innovative procurement procedures. This involves making the public tender more general with fewer specified requirements, so that the private actors them self have to provide the best solution and the municipality choose among the propositions [KMD, 2019b]. Thus, technological procurement's regarding IoT is more complex and require a higher competence level among the decision-makers in the municipality [Guenduez et al., 2020, KMD, 2019b]. This is because the sensor alternatives greatly varies in terms of technological requirements regarding range, network, open data and IoT platforms. Thus, a challenge with IoT-enabled smart city initiatives is the strain they put on municipal resources.

In terms of digital infrastructure, two out of the four municipalities have chosen a LoRaWan-network and have left development and maintenance of the sensor network to external partners. M1 uses a private partner to maintain the LoRa-network, while M2 uses a public company. This is because the municipalities do not have capacity to handle the network on a day to day-basis. In example, M2 stated that they much rather outsource the network management so that their IT-department are able to handle their day-to-day work. Also, when asked why the two municipalities chose this network, the municipalities answered that they were inspired by other municipalities. They find that with successful network implementation in other municipalities, the network will most likely be successful in their municipality as well. In regards to relying on external system providers, the research of Wirtz et al. [2019] finds that the public sector organisation has to be cautious of the implications for their strategic decisions with regard to IT and data security. The research have found that "governments and public organisations need to be strategically flexible in terms of providing an adaptive infrastructure that is able to cope with ever-changing security threats in the heterogeneous and dynamic IoT context". With this the authors mean that public decision-makers have to understand the importance of strategy as an influential building block in the context of the IoT and that they have to be able to challenge their strategy on a regular basis to adjust it over time. The authors also suggest that decision-makers have to secure an adaptive infrastructure, which can become more difficult when development and maintenance are outsourced. Wirtz et al. [2019] also state that coping with the ever-changing security threats in the heterogeneous and dynamic IoT context is important to ensure security and public trust when adopting IoT services or solutions.

6.2 Collaboration with private actors and academia

Through their study, Wirtz et al. [2019] have identified the significant role of private companies and respective networks for IoT-projects. In addition, Falch and Maestrini [2019] have found that outsourcing and collaboration with private actors is becoming increasingly important for public sector organisations. Collaboration with private actors was also seen as important in the case-municipalities, and it is a big focus area in the digital strategy of public sector in Norway [KMD, 2019b]. Further, it has been found that when private and public actors collaborate on IoT-projects, the actors take on different roles [Falch and Maestrini, 2019, Cavallini et al., 2016]. Usually the municipality handles regulation, while the implementation most often is performed by the private partner. Funding, however, can be private as well as public, and the public partner can also be involved in the design, monitoring, and management of a project [Falch and Maestrini, 2019]. Theory has also found that public actor goals of establishing such relationships is to partially transfer the risk in service provision from the public to the private sector and make use of private sector capabilities, such as capital or skills, in order to expand or increase efficiency in public services [Wirtz et al., 2019, Falch and Maestrini, 2019]. In the case-municipalities, empirical findings suggest that the aim of public-private partnerships predominantly is driven by the need of technological competence. Further, in terms of facilitation for local industrial growth, Falch and Maestrini [2019] have found that municipalities can improve and encourage growth in their local community through collaboration with private actors. The empirical findings in this regard, indicated that the case-municipalities in fact collaborate with local private actors to stimulate economic growth and development in the local community.

Next, it was found that the case-municipalities collaborate with a wide range of private actors on IoT-projects, both large enterprises, smaller and more local companies and start-ups. They report that they often have to find the private partners through networking in their local community or at national conferences, or that they confer with other municipalities to find good private partners for their IoT-projects. They see this process as complex and time-consuming, and three out of four case-municipalities request better overview of potential ecosystem actors. These findings correspond to the analytical findings of Rambøll Management Consulting AS [2019], that found that Norwegian municipalities in general find the ecosystem of private actors to be complex and difficult to navigate. However, the number of involved and unique actors in the IoT-ecosystem of the case-municipalities, suggest that they have a certain overview and that they make an effort into involving more actors. Further, one can argue that the case-municipalities show a culture for local inclusion and creative encouragement in terms of including the local private actors, and that they have a willingness to explore potential new service areas.

Velsberg [2019] have studied private-public goal-alignment and observed how IoT-smartness is best achieved when actor goals align or complement each other. The authors further state that when this happens, technology can be used to both enhance and transform organisational practices and processes, and the organisational culture can further support change. Through the interview with M2, it was found that the municipality establish that their vision and goals align with those of the private partner before officially initiating projects. M3 state that their long-term goal with smart city-projects often is to make a service offer that can be transferred to other municipalities. This is a focus for two reasons; 1) M3 want their project to help reduce the number of duplicate IoT-solutions and 2) they want their solution to be scale-able in order to generate more interest both commercially and in private sector. M3 further state that they wish for the private actor to be a technical expert and for them to be a municipal expert providing crucial insight into creating the perfect service fitting to their goals. This view of looking at goal-alignment, it found in the literature as an important success-factor. Namely, Russell and Smorodinskaya [2018] have researched the subject of innovation partnerships among public and private sectors and points out the importance of building required tools for an interactive dialogue and to work jointly to secure sustainable growth when purposes align [Russell and Smorodinskaya, 2018]. This is to ensure continuously aligning development strategies and implementation processes.

Further, Hasche et al. [2019] points towards the fact that academia is an important actor in collaboration. An interesting finding from our analysis showed that all case-municipalities collaborated with academia to some extent. M1, M3 and M4 are in an unique position, situated in close proximity to a university aiding them through research and development in IoT-projects. M2 are not closely situated to a university, but still utilizes high schools to motivate and engage at a young stage. Despite this, all case-municipalities pointed out how collaboration with academia can be challenging because the municipal project often are under strict time-concerns and research organisations often take to long to provide them with the necessary insight for the project. Further, the approach of the case-municipalities can be qualified as the bottom-up approach to innovation [Lee et al., 2014, Mora et al., 2019]. This is because they aim to include multiple local actors in their innovation efforts, focusing on market-oriented and efficient public services. Thus, Lee et al. [2014] have found that such municipalities often become facilitators and central coordinators of the partnerships and the IoT-ecosystem. This correspond with the empirical findings and how the projects seem to be organized to include multiple actors.

6.3 IoT increasing citizen participation

Multiple authors have highlighted the importance of the citizens role in IoT-enabled smart city development [Giffinger et al., 2007, Guenduez et al., 2020, Hasche et al., 2019, Berntzen and Johannessen, 2016]. Berntzen and Johannessen [2016] state that people and communities are a major success factor in Norwegian "smart cities" and that increased participation leads to better service solutions and more democratic involvement. Further, Guenduez et al. [2020] have found that IoT utilization provide new possibilities for citizen involvement through the citizens becoming co-designers and contributors to government services. Thus, in this section we compare the empirical findings of how the case-municipalities collaborate with citizens to theory findings from literature.

First, citizen participation can be achieved in different ways. The most commonly used methods is for citizen involvement is active forms of participation, such as focus groups, surveys, polls, dialogues, and town-hall meetings [Berntzen and Johannessen, 2016]. In the case-municipalities, citizens are invited to participate through workshops, panel testings, surveys and city labs. A challenge with this form of active collaboration, is that citizens may be reluctant to join a focus group or join a town hall meeting, due to time and space constraints [Berntzen and Johannessen, 2016]. Thus, Guenduez et al. [2020] have found that sensors and connected devices will provide citizens with new and improved methods of active participation through open innovation and collaboration. The authors further states that IoT can create and improve the municipal environment so that involvement and participation enhances public service delivery and strengthen community factors. This can be done by showcasing application areas for IoT to citizens and encourage them to learn more about IoT-use. However, in order to gain the full benefits of IoT in citizen collaboration, the municipality have to facilitate and encourage citizens to gather and share sensor data [Guenduez et al., 2020]. The authors further state that providing personalized feedback or sense making about the real purpose of data-sharing is important to secure the data flow Guenduez et al. [2020].

On the other hand, IoT may also provide the case-municipalities with improved methods of passive citizen participation. In example, as a driver on the smartly lit municipality road or a user of M4's public parking space with sensors, citizens become part of value creation in government services which results in more citizen-centered governance of public services [Guenduez et al., 2020]. The citizen simply contribute to the overall data life cycle by using, or being surveyed, by the sensor within the public infrastructure [Guenduez et al., 2020]. Also, "passively" generated data provide insights into the uses and effectiveness of services in key policy areas, such as transport, health, safety, and agriculture [Berntzen and Johannessen, 2016, Guenduez et al., 2020].

Regardless of method chosen, it has been found that IoT and new technology solutions can improve the value creation processes in the case-municipalities by actively or passively including all citizens. In this sense, smart technologies are also social technologies, enabling the participation of large groups of people. Further, it is found that many citizens actually want to share data due to personal affection, concern, and solidarity to their neighbourhood [Berntzen and Johannessen, 2016, Guenduez et al., 2020]. Further, it has been found that IoT utilization as a complementary top-down approach can help remove constraints of citizen participation, provide better service solutions and more democratic decision-making processes [Guenduez et al., 2020, Berntzen and Johannessen, 2016].

6.4 Inter-municipal collaboration in smart city development

There are few research articles assessing forms of collaboration among actors within public sector or inter-municipal collaboration. However, there are some Scandinavian studies that have explored inter-municipal forms of collaboration and the associated benefits [Helin, 2017, Juell-Skielse et al., 2017, Wiberg and Limani, 2015, Markendahl and Deij, 2018]. Similarly to these studies, our study have identified that the development of inter-municipal collaboration rests on both formal and informal voluntary collaboration structures and communication platforms. Further, it has been found that the aim of inter-municipal collaboration is to co-evolve capabilities by working both cooperatively and competitively with other municipalities in proximity to create better public services [Wiberg and Limani, 2015, Juell-Skielse et al., 2017, Markendahl and Deij, 2018].

Similarly with the studies of Wiberg and Limani [2015] and Helin [2017], the findings of this article have identified some informal structures of inter-municipal collaboration. It is not known for certain why these voluntary forms of collaboration occur, but the municipalities' local autonomy and scarce resources might have an effect. Analysis of the empirical findings have identified "knowledge communities". This form has characteristics of informal collaboration through networking and exchanging experiences with other municipalities at conferences and digital forums. In addition, the analysis identified "transferring solutions" as a commonly applied form of inter-municipal collaboration. The municipalities stated that they aim to apply other municipality's smart solutions to their own local environment, and visa versa. An identified challenge with this form of collaboration was stated by M2, who said that often the "great solution" was not necessarily working as described. A more general stated challenge from all municipalities was that a solution working in one municipality, not necessarily work in their own and that this was difficult to predict in advance. However, the positive aspects of this latter form of informal collaboration is that it limits the number of duplicate solutions which help simplify and improve the solution.

The formal inter-municipal collaboration structure of project based form also have similarities to the formal collaboration identified by Helin [2017] and Wiberg and Limani [2015]. These collaborations may range from being between only two municipalities to more joint initiatives with additional municipalities in a regional county and/or in a cross-regional context [Wiberg and Limani, 2015]. The municipalities invest both resources into a smart city-project which results in a product or service to be used by all involved municipalities. The analysis found that the case-municipalities can collaborate on a project-based basis both with smaller, surrounding municipalities and more similar-sized municipalities. Further, the analysis showed that size of the collaborating municipalities can have an effect on resource allocation and time of decision-making.

Generally, the aim of the formal and informal collaboration forms is to make the municipalities more efficient and sustainable in service provision to better meet quality requirements and ensure that people feel safe and secure [Wiberg and Limani, 2015, Hasche et al., 2019, Markendahl and Deij, 2018]. Wiberg and Limani [2015] further found that a reason for municipalities to collaborate has been because they share similar weaknesses, problems and challenges. Further, a study by Spicer et al. [2019] shows the importance of inter-municipal collaboration and suggest that municipalities tend to overlook the option of partnering with other municipalities in smart city development. The authors state that;

> *"With inter-municipal collaboration in such [smart city] projects, local decision-makers can exert more control over the process, ensure that data is collected, stored and used on their terms and best direct development to serve those most in need of digital opportunity. They would also be able to access additional sources of capital to facilitate development, while tapping into the policy and technical knowledge of staff in other municipalities. Most importantly, they would be able to place technology firms in the position of vendors, rather than decision-makers. Cooperation, therefore, could be one route for municipalities to ensure the capacity and scale to build smart cities, without losing control of the process or outcome."* [Spicer et al., 2019, p.71]

With this quote Spicer et al. [2019] presents the general benefits of inter-municipal collaboration on smart city projects and further aim to encourage municipalities to engage in this form of collaboration. As for the relevance to IoT of the findings of Spicer et al. [2019], it has been found that gaining control over the technology processes, securing data collection and storage processes is highly important for IoT-implementation.

All in all, three collaborative approaches across municipal borders have been identified throughout this article. The study has identified both formal and informal collaboration structures and attempted to list some characteristics of the structures through use of findings from interviews and other researchers findings. Despite the findings presented, it is important to state that more research is needed to gain a deeper understanding of the various forms of collaboration, benefits and challenges of inter-municipal collaboration – especially in terms of smart city-projects utilizing IoT.

7 Conclusion and contribution

Becoming “smart” and more effective when providing citizen services has become an important objective for every local public organisations across the world. In Norway, the municipalities become a central actor. In order to become "smart", the municipalities rely on both advanced technology (sensors and connected devices, open data analytics, Internet of things) and human capital (academia, competent private actors and other municipalities). This paper aims to investigate and discuss how IoT smartness is enabled in medium-sized municipalities in Norway and how municipalities collaborate with actors in the IoT-ecosystem.

It has been found that all case-municipalities work strategically towards smart city development and that they all structure the work via an assigned smart city workgroup. The aim of the smart city initiatives is to lower costs and to make the municipality an attractive place to live and work. Further, findings of this study suggest that decision-making and smart city development is largely driven by citizen needs. The case-municipalities encourage citizens and local actors to become engaged in the smart city-work and to provide their input through city labs, workshops, panel testings and surveys. Further, all municipalities utilized sensors and IoT in at least four technical sector-activities. The most common activity where IoT was tested, was in water temperature and air quality monitoring. It is found that the municipalities see IoT as a means to reach smart city-objectives, but not as a goal in itself. In terms of the collected data from the sensors, the municipality strive to open up the data sets and facilitate open innovation with local actors. However, there are challenges regarding data platforms, quality of data sets and competence in technology providers. The market and technology is seen as immature, so when sensors improve and mature IoT-pilots will more easily scale to operational public services.

Collaboration with private actors, academia and other municipalities have been seen as important. The case-municipalities aim to include both smaller and bigger businesses for increased technology competence and financial resources. The smaller companies is often local and operating in a niche market of IoT, while the bigger companies are national companies with a larger network and somewhat established ecosystem. The role of academia is to provide insight into technology development and the municipalities see collaboration with this actor as an beneficial investment for increased ICT competence in the future. However, findings of this study suggest that the IoT-ecosystem for collaboration is complex and difficult to navigate. This makes it challenging to find the right partner and the case-municipalities request a a better inter-municipal system to more easily navigate potential technology providers. Further, a contribution to the research on IoT-enabled smart city research is that inter-municipal collaboration is an important part of the smart city-initiatives. Formally, the municipalities collaborate on a project-basis and the structure of the collaboration can vary depending on the size of the contributing municipalities. In a more informal way, the municipalities share experiences and advice through networking and knowledge communities and through direct transfer of other municipalities' service solutions.

All in all, the empirical findings seems to support that IoT have the potential to make municipalities smarter by improving public services, efficiency of internal management and service delivery. IoT has also been found to somewhat drive collaboration with various actors. However, IoT as a technology is continuously evolving as the collected data reveal new application areas. This requires that the public sector are adaptable and future-oriented. Further, an important contribution of this article to the research of smart city research is the practical insights into smart municipal development. Also, this research is one of the few articles providing insight into how smart city development can be enabled through use of IoT. The findings from this research act as a starting point into gaining increased understanding of the complex processes of smart city development in municipalities.

8 Limitations and further research

Despite the paper's contributions, it does contain limitations. First, the results and reliability may have been influenced by single source bias as the interviews were with only one municipal smart city representative. Other views on priorities for smart city development might exist in the municipality. Further, as the IoT-ecosystems continuously evolve, some relationships among actors might not have been described. In order to control for this, municipal websites as well as reports and documents describing aspects of the IoT-projects have been read to supplement the data from the interviews. The focus of this thesis has been to map how IoT is being utilized in smart city development by focusing on a wide range of application areas in technical sector. Further research might focus on how the inter-relations among actors evolve over time by studying specific IoT-projects in even more detail.

Also, the smart city-projects focusing on the aspects of smart city development which not include IoT-technology, is outside the scope of this article. Hence, the article does not map the entire spectrum of smart city projects in the municipalities. Further research might focus on the whole range of projects regardless of technology in order to describe how IoT-projects in smart city development relates to other types of smart city projects.

The analysis showed that smart city development is not only about technology and collaboration, but also about organisational change and internal roles. Thus, an area for further research is to further analyze the internal municipal processes and organisational roles to gain deeper understanding of how smart city development changes a public organisation. Another interesting area for further research is to compare the findings from this study to findings from other case studies to see how results differ among municipalities of similar size, municipalities of larger size, and across country-borders.

Despite its limitations and scope, this paper hopes to make a valuable and unique contribution to smart city-research and research of how municipalities plan and utilize IoT for smart city development, as well as how municipalities collaborate with actors in the IoT-ecosystem. The findings from this study can help executives gain practical insight into the theory-heavy subject of smart city development.

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Appendix

A Norwegian municipal interview guide

Introduksjon
Intervjuerene presenterer seg selv og temaet for forskningen. Intervjuerene spør deretter intervjuobjectet om å presentere seg selv, sin rolle i organisasjonen og hvor lenge de har hatt denne posisjonen.

C1 - Innledende spørsmål

- Hva er kommunens hovedmål innenfor digitalisering?
- Hvilke prosjekter har kommunen startet innen digitalisering frem til nå?
- Vi ønsker å undersøke hvor langt kommunen har kommet med å ta i bruk sensorikk og IoT. Har kommunen tatt i bruk dette i dag?
- Mer spesifikt, hvilke kommunale sektorer bruker sensorikk/IoT-løsninger? Hvordan brukes teknologien innenfor disse sektorene? Kom gjerne med eksempler.
- Har kommunen et eget radionettverk (eg LoRA, NB-IoT)?
- Er dette nettverket for eksperimentelt eller kommersielt bruk i dag?
- Hvorfor valgte dere denne løsningen?

C2 - Strategi

- Vi har snakket litt om målene om digitalisering i kommunen. Har kommunen har en spesifikk smartstrategi? Og inkluderer den mål om bruk av IoT/sensorikk?
- Har kommunen fått forsknings eller innovasjonsstøtte for å realisere IoT-prosjekter?
- Hvor langt har dere kommet med å skalere opp IoT-prosjektene deres? PoC, pilot, integrert i drift Hvilke hindre ser dere for å videre skalere opp prosjektene?

C3 - Verdirealisering

- På hvilken måte hjelper IoT kommunen å nå mål innen verdiskapning?
- IoT og sensorikk genererer mye data. Hvordan ser kommunen for seg å dra nytte av data som produseres? Hvilke hindre ser kommunen for å utløse verdipotensialet ved bruk av IoT-løsninger?

C4 - Samarbeid

- Hvem er pådriver for IoT-prosjektene? Hvordan startet de?
- Hvilke faktorer er viktig for kommunen i startfasen av nye smart-prosjekter(IoT)?
- Hvilke aktører må involveres i smartprosjekter(IoT)?
  Hvordan involveres de ulike aktørene i prosjektet?
  Hva bidrar de ulike aktørene med?
  Hvilken rolle har de ulike aktørene i samarbeidet?
  Hvilke utfordringer opplever dere knyttet til samarbeid?
- Har kommunen inngått samarbeid med akademia med IoT-løsninger i dag? Hvilken rolle tok de i samarbeidet?

- Har kommunen inngått samarbeid med private aktører med IoT-løsninger i dag? Hvilken rolle tok de i samarbeidet?
- Har kommunen igangsatt/planer om å samarbeide med andre kommuner for å utvikle nye IoT-løsninger?

  Hvis ja, innenfor hvilke rammer skjer dette samarbeidet? Hvilke utfordringer opplever dere knyttet til interkommunalt samarbeid?

  Hvis nei, hvorfor har dere ikke igangsatt/planer om dette? Hvordan ser kommunen for seg å samarbeide med ulike aktører i fremtidige IoT-prosjekter?

C5 - Utfordringer

- Hva er de største utfordringene dere møter på ved bruk av sensorikk/IoT-løsninger?
- Hva må til for at kommunen kan løse utfordringene?

Chapter 8

Concluding remarks

This thesis aims to provide practical examples and an overall understanding of the state of smart city development across Nordic municipalities. The work brings value and originality by providing empirical findings to a heavily theorized area of research. By interviewing digitalization and smart city leaders in seven medium-sized municipalities in the Nordic region the thesis describe how smart city development is organized in the Nordic countries and how Norwegian municipalities utilize IoT for smart city development.

The first article of this thesis, aims to study how medium-sized municipalities in the Nordic region are organized for smart city development, and how the development is influenced by contextual factors. Further, the findings of this article suggest that defined long-term goals and strategies is needed for smart city development to mature, as well as a formalized organizational setup within the municipality. In addition, the findings suggest that support from a strategic facilitator to establish the goals and strategies is of importance for medium-sized municipalities to ensure the long-term focus of smart city development. Further, the empirical findings were placed in the context of contextual factors and country-level dynamics. It was found that there is a paradox between centralization and decentralization of smart city development, and that close collaboration and clearly defined roles are required to reap the benefits from local autonomy of municipalities and the synergy effects of centralized support and facilitation. Further, the findings suggest that local conditions such as economic factors and scarcity of resources act as a driving force to initiate smart city development. Last, we identify that the country-level approaches and regulations on innovation might influence smart city development in municipalities. However, more research is needed on the topic.

The second article aims to study how municipalities plan for and utilize IoT in smart city development and how they collaborate with actors in the IoT-ecosystem. The findings from this article suggest that all the Norwegian case-municipalities strategically work towards smart city development and structure their work via an assigned smart city work group. The aim of the smart city initiatives is to lower costs and to make the municipality an attractive place to live and work. The findings further suggest that decision-making and smart city development is largely driven by citizen needs in the Norwegian case-municipalities. It was found that the municipalities see IoT as a means to reach smart city-objectives, but not as a goal in itself. However, the municipalities strive towards open up data collected from sensors, but face challenges related to data platforms, data quality and the competence of technology providers. In addition, the findings suggest that the IoT-ecosystem is currently complex and difficult to navigate. Further contributions of this thesis has been the identification of inter-municipal collaboration as a method for medium-sized municipalities to increase success of IoT utilization in smart city development. Formally, the municipalities collaborate on a project-basis, and the structure of the collaboration can vary depending on the size of the contributing municipalities. In a more informal way, the municipalities share experiences and advice through networks and knowledge communities and through direct transfer of other municipalities' service solutions.

Despite the thesis' identified challenges related to smart city development in the Nordic region, all Nordic countries have been found to stand out as digital front-runners in Europe, as well as in a global perspective. Hence, smart municipalities in the Nordic region seem to be amongst the most advanced municipalities in the world. Thereby, smart city development in Nordic medium-sized municipalities may act as leading examples for smart city development in smaller communities in other countries. In Norway, all the case-municipalities have initiated IoT-projects within multiple municipal services, and their IoT-projects will continue to progress in scale and scope by continuously connecting more devices. Hence, future prospects of smart city development in Nordic municipalities have great potential and may include the use of massive IoT.

The thesis has also outlined areas for further research to better map the state of smart city development in municipalities. The analysis in this thesis has showed that smart city development is not only about technology and collaboration, but also about organisational change and internal roles. Hence, an area for further research is to map the roles and interests of the leaders and employees as well as internal processes in the municipal departments to understand how smart city development changes municipal service delivery.

In terms of how IoT can be utilized in smart city development, an interesting area for further research is to map how inter-municipal collaboration can make all types of public data more accessible through API's and open databases. Further, given the quite similar characteristics of the Nordic countries, there is a potential of cross-country collaboration on smart city development to improve public services at a municipal level. However, more research on the potential of such collaborations is needed.

Other interesting areas for further research includes comparison of municipalities of different size. First, further research is needed to map the effect of municipal size on utilization of IoT in different contexts. Second, more research is needed to further understand how contextual factors influences smart city development differently for municipalities of different size.

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Appendix

A Municipal size definitions

The size intervals and definitions by the statistical agencies in Denmark, Finland, Norway and Sweden.

<table>
<tr><th>Country</th><th>Size groups</th><th>Size metrics</th><th>Intervals</th></tr>
<tr><td rowspan="2">Denmark</td><td rowspan="2">(1) Rural municipalities
(2) Hinterland municipality
(3) Provincial city municipality
(4) Metropolian municipalities
(5) Municipalities in the capital region</td><td>Population size in the largest city in the municipality</td><td>(1) 0 - 30 000
(2) 0 - 30 000
(3) 30 000 - 100 000
(4) 100 000 -
(5) NA (considers proximity to the capital)</td></tr>
<tr><td>The number of workplaces</td><td>(1) 0 - 40 000
(2) 40 000 - 200 000
(3) 0 - 200 000
(4) 0 - 200 000
(5) 200 000 -</td></tr>
<tr><td rowspan="2">Finland</td><td rowspan="2">(1) Rural municipalities
(2) Medium urban municipalities
(3) Urban municipalities</td><td>% of population living in urban settlements</td><td>(1) 60-90% of the population lives
in urban settlements with a population
size below 4000
(2) 60-90% of the population lives in
urban settlements with
a population size between
4 000 - 15 000
(3) At least 90 % of the population lives
in urban settlements</td></tr>
<tr><td>Urban settlement size</td><td>(1) The largest urban settlement has
below 15 000 inhabitants
(2) The largest urban settlement has
between 4 000 - 15 000 inhabitants
(3) The largest urban settlement is at
least 15 000 inhabitants</td></tr>
<tr><td rowspan="3">Norway</td><td rowspan="3">(1) Small
(2) Medium
(3) Large</td><td>Population size</td><td>(1) 0 - 4 999
(2) 5 000 - 19 999
(4) 20 000 -</td></tr>
<tr><td>Bound costs of the municipality</td><td>(1) Low, (2) medium (3) high</td></tr>
<tr><td>Free disposable income of the municipality</td><td>(1) Low, (2) medium (3) high</td></tr>
<tr><td>Sweden</td><td>(1) Small places and rural
municipalities
(2) Larger places and
municipalities close to larger cities
(3) Large cities and
municipalities close to larger cities</td><td>Population size *</td><td>(1) 0 - 40 000
(2) 40 000 - 200 000
(3) 200 000 -</td></tr>
</table>

* Sweden uses commuting-patterns to further categorize the municipalities in sub-dimensions within each category.

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