The Impact of Digitalization on Urban Governance Sustainability Transformations

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A case study focusing on digital policy instruments used in the Copenhagen 2025 – Climate Plan

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Laura Sundsgaard
s2380889

Supervised by:
Dr. Le Anh Nguyen Long, University of Twente, The Netherlands
PD Dr. Matthias Freise, Westfälische-Wilhelms Universität Münster, Germany

Abstract

The focus of this thesis is on how digitalization is influencing the way the public sector designs, develops and implements solutions to sustainability challenges. Digitalization and sustainability are the two megatrends taking place in the urban century. However, there is little research on how these challenges interact, support, or hinder each other in the urban context. By answering the research question whether digitalization can promote urban sustainability transformations, this thesis aims to fill this research gap. For this purpose, a single case study based on a qualitative content analysis of Copenhagen's Sustainability Strategy is conducted, based on the Climate Plan (2012) and the associated Roadmaps (2017, 2020). Thereby, digital policy instruments are identified and classified into the types of *information*, *technology*, *analysis*, *efficiency,* and *flexibility*. Furthermore, based on Roger's (2004) attribute typology, digital policy instructions are found to offer great potential for innovation. The study of barriers to the implementation of digital policy tools, following the research of Mondschein et al. (2021) and Veselitskaya et al. (2019), shows that certain barriers have not been overcome. In particular, the fact that citizens are not involved in the development and design process of digital policy instruments, and thus are not participants in urban planning, is an important organizational barrier that hinders implementation.

TABLE OF CONTENT

1. Introduction

In recent decades, an ever-increasing interest in digital solutions has been observed in many areas of society. The COVID-19 pandemic alone with its need for distance between people has put enormous emphasis on the interest in digital solutions. Triggered by progress "in digital technologies such as artificial intelligence, big data analytics, cloud computing and the Internet of Things (IoT)" (Feroz, Zo, & Chiravuri, 2021, p.1), the digitalization of processes is already taking place in many areas and is leading to unprecedented changes in society, industry and organizations. Thus, it affects all areas of modern economy (Kokh, Kovaleva, & Ivanova, 2021) and is becoming increasingly important for all sectors, including public administration. Another major topic in the public, political and scientific debate is how to prevent or mitigate climate change (IPCC, 2014; NASA, 2021; Ziska & McConnell, 2016). Against this background, the focus of this thesis is on how digitalization is influencing the way the public sector designs, develops and implements solutions to sustainability challenges, including climate change.

The growing impact of digitalization could influence or change sustainability. Due to the transformative nature of sustainability, sustainability will be able to adapt to the new opportunities and threats of the digital age (Seele & Lock, 2017). Nevertheless, these two megatrends of digitalization and sustainability are not isolated from each other and must therefore also be considered jointly. This is particularly evident in the way the topic of sustainability comes up in the digitalization debate. Digitalization is perceived to have incalculable potential to achieve sustainability or at least to reduce the negative impact of humanity to the planet (Seele & Lock, 2017). For instance, there are reoccurring sustainability concerns about the climate friendliness of digitalization. These concerns are primarily about its impact on the environmental well-being i.e., the management of natural resources and care for future generations (Linkov, D. Trump, Poinsatte-Jones, & Florin, 2018). Due to the increasing use, the demand for server capacities is rising in particular, and as a result, both the electricity consumption and the demand for rare soil for the production of technical devices are increasing (Morley, Widdicks, & Hazas, 2018). A failure to account for digital waste and other unsustainable practices could threaten the long-term viability of public administration digitalization. At the same time, advancing digitalization could promise solutions for sustainability. The convergence between sustainability and digitalization is often perceived as a winning combination (Dyatlov, Didenko, Lobanov, & Kulik, 2019; G. George, Merrill, & Schillebeeckx, 2020; Seele & Lock, 2017). Digital technologies could help address major challenges to combat climate change and promote sustainable development (G. George et al., 2020). While it is not free of challenges, digitalization offers opportunities within and across organizational boundaries to overcome information deficits (Del Río Castro, González Fernández, & Uruburu Colsa, 2021). In particular, by improving administrative efficiency and promoting urban sustainability through an improved transparency and accountability, by increasing resource efficiency, accelerating discovery, by promoting (sustainable) education, and supporting evidence-based decision making (Del Río Castro et al., 2021). Concrete examples could be a 'transnational sustainability agency' or a digital 'global

participatory platform' driven through the possibilities of big data (Seele & Lock, 2017). "In conclusion, both megatrends, sustainability and digitalization, impose major transitions on our world and how we picture it" (Seele & Lock, 2017, p. 183). However, research on the interface between digitalization and sustainability is still new at the city level, particularly as it pertains to public administration.

Public administration is in the context of coping with the advancing digitalizing and the challenges through climate change of such extraordinary importance, since coping with these two megatrends must be done through concrete measures where people live. In 1950, 30 percent of the world's population lived in urban areas, and by 2050, the UN expects that 68 percent of the world's population is to live in cities (United Nations, 2019). Currently, more than half of the world's population (around 55%) now lives in urban centers (Keivani, 2010; United Nations, 2019) and this trend seems to continue. Researchers therefore also refer to the 21st century as the 'urban century' (Elmqvist et al., 2019; Keivani, 2010). Urbanization offers new opportunities as the concentration of people and activities in high densities make it possible to use resources more efficiently than in rural areas. As Rosenzweig and Solecki (2028, p.757) state "cities [are] at the opportune level of governance to be the main implementers of climate action in regard to both mitigation and adaptation". Cities with their high concentration of people and activities have created complex social structures and economic challenges (Keivani, 2010). These often lead to severe environmental impacts. For example, cities are the largest contributors to air, water and soil pollution (Keivani, 2010). Due to these major societal challenges and the growing importance of cities, they need a fundamentally new, holistic perspective to understand the challenges, to align different priorities and goals, and to strategically plan policy and governance for a better urban future (Elmqvist et al., 2019). Above all, this is possible through the transformation of sustainability governance (Rosenzweig & Solecki, 2018), since urban governance and institutional capacity are emphasized as essential prerequisites for addressing the key challenges of urban sustainability (Keivani, 2010).

Thus, we observe a growing urbanization and desire for digitalization, but at the same time an urgent need for a more sustainable society to help the planet survive. To ensure such a sustainable development, we need to know the linkage between digitalization and sustainability (Dameri et. al, 2019). This could enable municipalities (even ones with small budgets) to make more sustainable policy decisions. Furthermore, there is a lack of research on the interface between digitalization and urban sustainability transformations in an urban context, and thus a knowledge gap. Therefore, research in this area is not only of societal but also of scientific relevance. Hence, this thesis aims to understand the impact of digitalization on urban sustainability transformations which could help to set urban policies to achieve and protect environmental sustainability. To address the resulting gap in knowledge concerning public administration's digitalization in Europe and its promise for sustainability, this thesis will address the following explorative research question:

Can digitalization promote urban sustainability transformations?

To answer this overarching question, this thesis explores the impact of digitalization on urban sustainability transformation, by a case study of Copenhagen. Copenhagen was selected based on the hypothesis that the more a state/society is digitalized, the more digitalization will be found as a factor in its Sustainability Strategy. As the capital of Denmark, Copenhagen is a city with outstanding ambitious goals in this context. Copenhagen has set itself the goal of being completely carbon neutral by 2025 (Copenhagen, 2012). Therefore, the case study on Copenhagen is conducted as a content analysis based on the policy paper 'Copenhagen 2025 – Climate Plan', which declares policy initiatives to achieve Copenhagen's aim to become the first carbon neutral city worldwide by 2025, as well as the policy papers 'Copenhagen 2025 – Climate Plan Roadmap 2017-2020' and 'Copenhagen 2025 – Climate Plan Roadmap 2021-2025'. This case study is conducted using a closed codebook and is structured by the following sub questions:

- *To what extent does digitalization determine the policy instruments in the Climate Plan of Copenhagen to become carbon neutral by 2025?*
- *Why do we see digital policy instruments in the Climate Plan of Copenhagen?*
- *How can the digital policy instruments in the Sustainability Strategy of Copenhagen be classified?*
- *How can the degree of usage of digital policy instruments in Copenhagen's Sustainability Strategy be explained?*

This thesis will first give a brief overview of the current state of research on digitalization and sustainability in the urban age (2). Based on this, the concepts of urban governance (3.1), urban sustainability transformation (3.2) and digitalization (3.3) that are important in this case study will be conceptualized. The following case study is structured according to the above-mentioned sub-research questions (5) and closes with a conclusion (6).

2. Digitalization and Sustainability in the Urban Century

In this urbanized century, the prevention and consequences of climate change, as well as the advantages and disadvantages of the digitalization of processes, are a major and important social topic. This section examines the extent to which this is also the case in the academic literature.

To be able to examine the current state of research, a systematic literature search is carried out in the *Web of Science* and *Scopus* databases. Different search operators (*Digitalization*; *Sustainability*; *Urban*) are used, also in combination with each other in two different time periods (*2000-2021*; *2016-2025*) (Table 1), to be able to see how the state of research is developing. This systematic literature search shows that the fields of *digitalization* and (especially) *sustainability* are highly researched fields in the last 20 years. The combined search of *digitalization* and *sustainability* also shows that some researchers are already investigating these two megatrends together and looking at how they influence each other. However, the extended search with the additional search operator of *urban* shows

significantly fewer hits. On the one hand, this could indicate that these initiatives happen most of the time rather on national than local level. On the other hand, that fewer researchers explicitly embed their research in the phenomenon of urbanization. Thus, it could imply that there is only little research on how urban governance can deal with these mutually influencing challenges. Overall, there seems to be a strong increase in research. Compared to the period between 2000-2021, there is a clear majority weighting of research in the last five years (Table 1).

	Web of science		**Scopus**	
Search operators	2000-2021	2016-2021	2000-2021	2016-2025
Digitalization	1.489	1.199	16.084	13.018
Sustainability	181.664	97.806	251.142	136.236
Digitalization AND Sustainability	84	80	597	572
Digitalization AND Sustainability AND Urban	9	8	50	49

Table 1. Systematic Literature Search on Digitalization and Sustainability in the Urban Century.

3. Conceptualization

When reviewing a wide variety of research in these thematic areas, it quickly becomes clear that the terms *urban governance*, *urban sustainability (transformation)* and *digitalization* are not easy to define. They are so complex that a more precise explanation of how they are to be understood in this thesis is needed, and thus will be conceptualized in the following chapter.

3.1. Urban Governance

As urbanization accelerates, cities are becoming more complex. So are the challenges cities face - such as climate change and digitalization, which make it increasingly difficult to run cities. Meeting these challenges will therefore require unprecedented transformative solutions for sustainability (Elmqvist et al., 2019). This requires the action of urban centers through governance.

There is no consensus on the exact meaning of *governance* (Knill, 2004; Lange, Driessen, Sauer, Bornemann, & Burger, 2013). Not even on the range of phenomena that can be subsumed under the term *governance* (Lange et al., 2013; Treib, Bähr, & Falkner, 2007). Thus, there is a wide range of different understandings in the academic and political debate. The concept of *governance* has emerged in political and social science as "a response to the growing awareness that governments are no longer the only relevant actors when it comes to the management of societal issues" (Lange et al., 2013, p. 404). In contrast to the term *government*, which represents the classical notion of a government focused

on the political-administrative system, the term *governance* is understood as a process with a multitude of actors in fragile instances of control. It captures novel dynamics of governance, including non-hierarchical forms such as network arrangements, in which the boundaries between the public and private sectors blur (Lange et al., 2013). Governance is thus accompanied by a shift in the perception of power from a 'power over' to a 'contextual power to' (Pierre & Peters, 2000; Schindler, 2010) and a change from 'constraining' to 'enabling types of politics' (Schindler, 2010). Thus, governance refers to the process of delivering state services through the involvement of non-state actors (Jones & Evans, 2006; Keivani, 2010; Werna, Keivani, & Murphy, 2009). In this thesis, *governance* is understood as a process of - more or less institutionalized - interaction between public and/or private institutions that ultimately aims at the realization of collective goals (Lange et al., 2013).

Urban governance is thus comprehended as the governing of urban areas. Like governance it is constantly in a process of change (Rosenzweig & Solecki, 2018). In this continuous process, *urban governance transformations* are consequently necessary to adapt governance to new challenges such as climate change. The understanding of *urban governance transformation* in this thesis is based on Rosenzweig and Solecki's (2018) understanding. For them, transformation is both a 'state' and a 'process'. The transformative adaptation of cities has several stages, namely collapse, resistance, resilience, and transformation. Through transition can cities go through these stages in either direction: "backward, from resistance to collapse, or forward, from resistance to resilience" (Rosenzweig & Solecki, 2018, p. 756). At the same time, transformation occurs as a process through the passage of different stages (Figure 1).

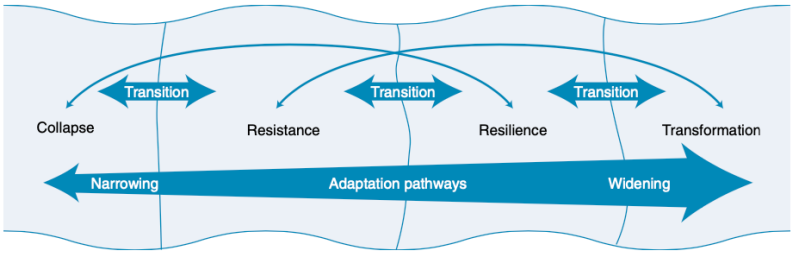

Figure 1. Adaption transitioning pathways by Rosenzweig and Solecki (2018).

To adapt control to new challenges such as digitalization or climate change, *urban governance transformations* are necessary. *Urban governance* is thus always in a process of change (Rosenzweig & Solecki, 2018).

3.2. Urban Sustainability (Transformation)

Due to its holistic character and normative dimension, the term *sustainability* is difficult to define. It is a rather high complex concept with multiple facets (Del Río Castro et al., 2021). Supported by extensive literature, considerable efforts have been made to define sustainability. However, the concept of sustainability is controversial (Kohler et al., 2019). Seele and Lock (2017) even state that it has been

misused all too often so that the actual meaning has been weakened. Some scholars even state, that the current lack of consensus undermines its implementation (Waas, Hugé, Verbruggen, & Wright, 2011). “Sustainability has become a moral and economic imperative, since nature, society and businesses are strongly intertwined, affecting the valuation of any organization” (Del Río Castro et al., 2021, p. 3).

Although there is no universal definition, most scholars agree on the basic principles in which sustainability is grounded: normativity, equity, integration and dynamism (Del Río Castro et al., 2021; Waas et al., 2011). Furthermore, there is a broad scientific consensus on the concept of balanced articulation of three pillars: social, environmental, and economic sustainability (Biermann, Kanie, & Kim, 2017; Cheong, 2017; Del Río Castro et al., 2021; European Union, 2019; Osburg, Lohrmann, 2017). Building on this, sustainability can be understood as the process of improving human progress while maintaining the resilience of economic, social and environmental systems (Munasinghe, 2004). In this context, social sustainability involves society's willingness to maintain community well-being, equity and intergenerational justice, combined with trust and ethical behavior. Environmental sustainability, on the other hand, is linked to the ability of ecosystems to sustain their purposes in the long term. Lastly, economic sustainability is understood as a ‘normative concept’ that refers to the ability to optimize the use of available resources efficiently and responsibly to maximize profitability over time (Del Río Castro et al., 2021; Osburg, 2017). Sustainability thus entails some notion of permanence and future viability, harmonious coexistence of nature and humans, conservation, equity and fairness, equitable and efficient allocation of resources, and environmental friendliness (Basagio, 1995; Costanza & Patten, 1995; Del Río Castro et al., 2021). Transferred to cities, *urban sustainability* is understood as meeting the needs of the inhabitants without creating unsustainable demand for local and global energy sources (Alberti, 1996). In this thesis, *urban sustainability* is also viewed with a particular focus on achieving carbon neutrality.

Such *urban sustainability* can only be achieved through a transformation of urban governance (Figure 1) by making sustainability a focus of governance. The understanding of *urban governance transformation* on which this thesis is based was in fact developed in the field of urban sustainability. Rosenzweig and Soleki state that “[t]he term ‘transformation’ is invoked to describe what cities must do to simultaneously improve climate resiliency and achieve the positive effects of low-carbon sustainable development.” (Rosenzweig & Solecki, 2018, p. 756). As a place where sustainability and digitization potentially meet, urban centers as Copenhagen are important objects of study when it comes to understanding fundamental urban sustainable transformation. The capacity for such an urban sustainability transformation is called *transformational capacity*. Wolfram (2016) defines urban transformative capacity as the ability of an urban system (including physical and human dimensions) to reconfigure and move towards a new and more sustainable state. He identified several components that determine the extent of transformational capacity in urban areas and enable or drive purposeful systemic change

towards sustainability. It focuses on institutional and processual aspects that can lead to sustainability transformation (Castán Broto, Trencher, Iwaszuk, & Westman, 2019). Just like urban governance transformations in general, the process is not linear. Instead, it is an ongoing process of social learning, where sustainability goals are seen as a 'moving target' and are never really achieved (Castán Broto et al., 2019).

3.3. Digitalization

In this urbanized century, a trend "of digital-based urbanization is occurring" (Anthony Jnr, 2021, p. 299). *Digitalization* is thus a process that is already taking place. Digital technologies are transforming the entire economy and society (Kokh et al., 2021). The flood of data processed by smart algorithms offers tremendous connectivity and computational power that, combined with traditional methods and contextual nuances, provides unprecedented opportunities to explore, to optimize and innovate aspects that were previously unfathomable (Del Río Castro et al., 2021; Hey, 2009; Manyika et al., 2011). Thus in this thesis, *digitalization* is generally understood as the use of digital technologies to provide new value-producing opportunities (Del Río Castro et al., 2021; Gartner, 2020). It consequently refers to a socio-technical method for improving social and institutional contexts through the adoption of digitalization techniques (Anthony Jnr, 2021; Seth, Talwar, Bhatia, Saxena, & Dhir, 2020). Because of its extraordinary ability to address complex societal issues, it has become an integral part of government agendas (Del Río Castro et al., 2021; Etzion & Aragon-Correa, 2016). For example, the digital revolution offers a powerful tool for building smart green growth (Perez, 2019) and sustainable governance (Etzion & Aragon-Correa, 2016), primarily based on the use of the so-called 'data revolution for sustainable development' (Del Río Castro et al., 2021; Jacob, 2017). "The digital transformation of government bodies is a global trend in the state administration system and in the provision of public services." (Kokh et al., 2021, pp. 250-251). The digitalization of the administrative sector and of government is often referred to as *e-government* (Schou & Pors, 2019). E-government is defined as the intensive or general use of information technologies in the administration for the provision of public services, the improvement of the effectiveness of the administration and the promotion of democratic values and mechanisms (Gil-García & Pardo, 2005). Digitalization, in the form of the explosion of digital information throughout society and the use of information and communication technologies (ICT) in administration, offers the potential of more efficient, transparent and effective administration. (Gil-Garcia, Dawes, & Pardo, 2018).

Regarding *digitalization* specifically in the urban context, it is important to be aware that urban operations are shaped by environmental, social, technical and economic impacts. Understanding these impacts is key for municipalities to unlock opportunities, especially to make municipalities more digital. This is driven by a *digital transformation*, which refers primarily to the transformations required to

increase digitalization based on a digital policy (Anthony Jnr, 2021). Thus, the transformation of urban governance (Figure 1) is also taking place in this field.

As a result, *digital transformation* is targeted by municipalities as a goal for a lasting future. Consistent with Anthony Jnr's (2021) understanding, *digital transformation* refers in this thesis to a broader approach in order to "transforming cities at different levels (e.g., people, governance, technology, strategy, culture, leadership, etc.) through digital concepts and technologies" (Anthony Jnr, 2021, p. 307). The starting point for all stages of the digital transformation is the digitization of analogue sources, e.g. the measurement of CO2 emissions into the environment, or the measurement of current traffic data, as well as the conversion of paper documents into digital documents (Anthony Jnr, 2021). Such a *digital transformation* can thus be interpreted as an innovation process to be pursued through urban governance (Schou & Hjelholt, 2018).

3.3.1. Innovative Potential of Digitalization

The digital transformation is supported by policy initiatives. To examine whether policy initiatives have potential for innovation and why certain policy initiatives are used, Roger's (2004) attribute typology can be used. Developed under the title 'the diffusion of innovations' it attempts to explain how and why certain ideas and technologies expand. It defines five attributes of innovation that predict their adoption rate: *relative advantage*, *compatibility*, *complexity*, *observability* and *trialability* (Rogers, 2004). Not all qualities have to be equally present in an initiative in order to be applied. In fact, Rogers assumes that these qualities interact with each other. Therefore, they must be assessed as a whole in the evaluation. For example, an innovation can be very complex but still be adopted and spread, if it is also very compatible and offers a big advantage over current tools. Then its innovation advantages outweigh its complexity (Rogers, 2004).

3.3.2. Barriers of Implementation

In the diffusion of *digital transformation*, it is also interesting to understand what enables and what are the barriers in the implementation of digital solutions (Mondschein, Clark-Ginsberg, & Kuehn, 2021). Current research focuses on implementation actors, public-private partnerships and principles of urban planning (Anthony Jnr, 2021; Mondschein et al., 2021; Veselitskaya, Karasev, & Beloshitskiy, 2019). Mondschein et al. (2021) observe that barriers can be both organizational and technological. For example, outdated infrastructure represents a significant technological barrier for smart cities. Organizational issues, such as different goals between stakeholders in combination with already existing operational practices and organizational structures, represent an organizational barrier (Mondschein et al., 2021). Veselitskaya et al. (2019), on the other hand, state that the questions of which actors are involved in urban planning, how the principles of urban planning of a municipality are designed and what mechanisms for implementing public-private partnerships exist are decisive for how 'smart' a city is. The

principles of the urban planning process include all "activities aimed at infrastructure development, regulation of construction and land use, and environmental protection" (Veselitskaya et al., 2019, p. 89). The role of public-private partnerships is crucial because they enable not only the development of relations between state bodies and business, but also the attraction of additional private resources to the areas under state jurisdiction (Veselitskaya et al., 2019). This has the potential to improve the efficiency of the use of budgetary funds and the effectiveness of the implementation of state and municipal projects (Veselitskaya et al., 2019). Beyond, the composition of the participants in urban planning, the program of urban development as well as their effectiveness. Especially their functions and ownership play an important role (Veselitskaya et al., 2019).

4. Research Method

This section presents the research method used in this thesis, which is a qualitative study that investigates whether digitalization is used to support urban sustainability transformations. For this purpose, this thesis examines exploratively a single case using a content analysis. It aims to take advantage of the potency of case studies to develop hypotheses and explore the causal findings of mechanisms (Gerring, 2011).

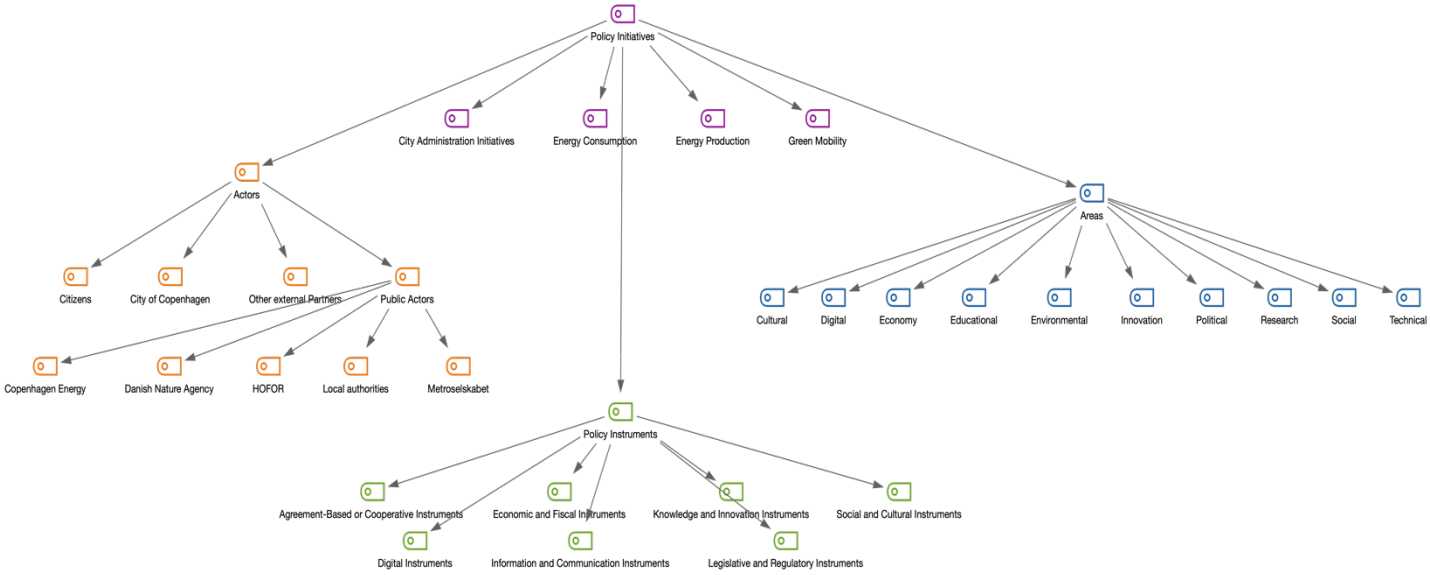

Figure 2. Coding Tree.

A content analysis is a research tool that enables the researcher to examine qualitative data for the presence of specific themes, concepts or words and to quantify as well as analyze their presence, meanings and relationships to each other (Columbia University, 2019; Hsieh & Shannon, 2005). The content analysis used in this thesis makes use of a closed codebook (Figure 2), which offers advantages that are particularly important in exploratory research and theory development, which are the objectives of this thesis. Figure 2 depicts the main codes and sub-codes, and how they are related to each other. The codebook distinguishes between four superordinate codes: *policy initiatives*, *policy instruments*, *areas*, and *actors*, which all contain sub-codes (Figure 2). The coding in this thesis is done in MAXQDA

2020 in three rounds (Figure 3). It has been checked by fellow students to minimize biases in interpretation.

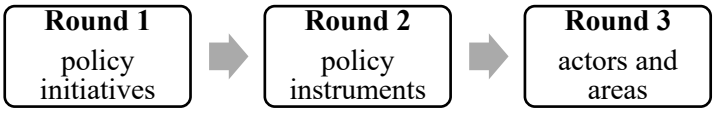

Figure 3. Coding Rounds.

First, the *policy initiatives* are identified in all three policy papers. This offers the possibility of assigning the examined policy instruments, areas and actors to individual initiatives in a structured way and prevents incorrect multiple coding. In this thesis, measures planned to achieve the climate targets are coded as *policy initiatives*. The examined policy papers divide their policy initiatives into four areas (*energy production*, *energy consumption*, *green mobility*, *and public administration initiatives*), which have been included in the codebook as sub-codes.

In the second round, *policy instruments* are coded to examine how the public authority tries to implement its policy initiatives. Policy instruments are tools of governance (Howlett & Ramesh, 1993) and thus, used by the government to implement its policy objectives by influencing the behavior of citizens and other actors such as businesses (Hood, 1983; Lascoumes & Galès, 2007; Peters, 2000; Schneider & Ingram, 1990). Table 2 lists all the sub-codes that fall under the main code *policy instruments*. There are different approaches to classify policy instruments (Dahl & Lindblom, 1953; Lowi, 1964; Salamon & Lund, 1989). This thesis is largely based on the classification by Bouwma et al. (2015), who distinguish between the domains in which instruments are deployed, that is *legislative and regulatory instruments*, *economic and fiscal instruments*, *agreement-based and cooperative instruments*, *information and communication instruments*, and at last *knowledge and innovation instruments*. This classification is thus used as basis for the subcodes of policy instruments. For a holistic view of all policy instruments, the categorization was extended by *social and cultural instruments* (ipbs, 2021). To enable the investigation to ascertain whether digital approaches have been used and how they are designed, the category of *digital instruments* was added to the codebook as well. Without this additional category, all digital instruments would fall under knowledge and innovation instruments and would therefore be more difficult to identify. Since this thesis is about the impact of digitalization on urban sustainability transformations, that would be an obstacle. Furthermore, the definition of digital instruments as policy instruments postulates the hypothesis that public authorities already use a variety of digital tools to implement policy initiatives. Within a policy initiative, several policy instruments can be used to achieve its aim. Thus, multiple coding of different policy instruments within a policy initiative is possible.

A summary of the different *policy instruments* can be found in the table below.

	definition	example
legislative and legal instruments*	binding requirements are imposed by a public authority, which sanction non-compliance	regulations, laws, directives
economic and fiscal instruments*	market mechanisms are influenced by a public authority	subsidies, tax increases or decreases, or lending require
agreement-based or cooperative instruments*	instruments that a public authority jointly decides on with other actors on a voluntary basis	cooperative agreements
information and communication instruments*	unilateral communication by providing information on specific issues to stakeholders through a public authority	information campaigns, targeted education program, provide product-related information, labelling
knowledge-based and innovation instruments*	jointly expanding the knowledge of actors involved through social learning	living labs, creative workshops, the creation of new business plans or the exchange of best-practice solutions
social and cultural instruments**	instruments influencing the societal behavior and the interwoven relationships between cultural dynamics and the ecosystem contained therein	include cultural heritage sites, indigenous and community protected places
digital instruments*	instruments influencing the behavior of the population through the possibilities offered by digitalization	data collection, computation, and visualization, including digital and electronic communications, network and information security, digital infrastructure

Table 2. Classification of policy instruments.

* Definition based on (Bouwma, Gerritsen, Kamphorst, & Kistenkas, 2015)
** Definition based on (ipbs, 2021)
*** Authors own definition.

In the third round, the *areas* in which the policy initiatives and instruments take place and the *actors* of the policy initiatives are identified. The assignment of policy initiatives and instruments to different *areas* offers to gain a better understanding of the context in which the policy initiatives or the instrument are motivated. Thus, the areas are divided into subcodes, which are mainly adapted from Doost Mohammadian and Rezaie (2020) who defined aspects of sustainable development in a model. Based on the common understanding that sustainable development is based on three pillars – social, economic, and environmental sustainability – Doost Mohammadian and Rezaie have developed a model that extends the original three pillars of sustainable development, by assuming that it is based on a total of seven aspects. Namely *economy, social, environmental, political, cultural, educational, technical* (Doost Mohammadian & Rezaie, 2020). As the entire policy papers were created in the light of climate change,

the motivation behind all initiatives is *environmental protection*. Thus, *environmental* is only explicitly coded if no other area can be identified *and* the motivation of environmental protection is explicitly mentioned. The seven aspects are complemented by the *innovation* and *digital* codes in the codebook to reflect all possible contexts of policy initiatives and instruments. To identify who is to participate in the development and implementation of the policy initiatives, the *actors* code was used. Since actors can enable or be barriers of the implementation of digital policies (Veselitskaya et al., 2019) is it interesting to look at the actors of policy initiatives. Furthermore, it is seen rather often that citizens are the users of digital solutions that have already been developed (Acco Tives Leão & Canedo, 2018). It is questionable, whether they are already involved in the development of these solutions or whether the state rather sees them as 'customers' to whom the digital solutions are only presented as a finished product in the hope that they will implement them. Hence, their role must also be examined. For this, subcodes were again formed that would most likely be part of the climate strategy: the *City of Copenhagen*, *citizens*, *other public actors*, and *other external partners.* Other external partners include private actors that do not act as private individual/citizens. For example, companies fall under this category. The other public actors have further subcodes, which could be identified in the examined policy papers, consisting out of: *Copenhagen Energy*, *Danish Nature Agency*, *HOFOR*, *Local authorities* and the Metro company (*metroselskabet*).

5. Case Study: Copenhagen

To investigate whether digitalization can support urban sustainability transformations, this explorative, qualitative research is based on a case study of a highly digitalized and sustainable municipality – Copenhagen. As the capital of Denmark, Copenhagen is known for its green orientation and sustainability (Fields & Renne, 2021). It was the host of the 2009 United Nations Climate Conference, which recognized climate change as one of the biggest challenges in present time and discussed how funds for climate adoption policies can be secured (Liverman & Billett, 2010). The city has outstanding ambitious goals in the context of sustainability. Already in 2012, the city has committed itself publicly to a climate adoption policy, the 'Copenhagen 2025 - Climate Plan'. Aim of this Climate Plan is to become the first completely carbon neutral city in the world by 2025 (Copenhagen, 2012). This early Sustainability Strategy makes Copenhagen one of the so-called 'early adopters' in climate change adoption policies (Olazabal, Galarraga, Ford, Sainz De Murieta, & Lesnikowski, 2019). In addition, Denmark as a whole is known for its level of progress in the digitalization of public administration (Scupola, 2018) and ranks very high in European comparison (European Commission, 2020a). The basis for the content analysis of this case study is formed by the Climate Plan and is complemented with the policy papers 'Copenhagen 2025 – Climate Plan Roadmap 2017-2020' and 'Copenhagen 2025 – Climate Plan Roadmap 2021-2025', which provide a report on the respective interim status of the innovations and measures. In addition, they present the upcoming policy innovations in the respective period in greater detail. Together, these documents constitute the Copenhagen Sustainability Strategy. The qualitative analysis is based on these three policy documents and is structured according to the sub-research questions.

This analysis first examines the original climate plan with regard to the extent to which digitalization is reflected in the used policy instruments (5.1.1) and why those digital policy instruments were used in the first place (5.1.2). It then examines the overall Sustainability Strategy, to classify the digital policy instruments used (5.2). Finally, possible barriers to implementation will be examined in order to explain the frequency of usage of digital policy instruments (5.3).

5.1. Digitalization as a policy instrument in the 'Copenhagen 2025 – Climate Plan'

To be able to examine whether digitalization can promote urban sustainability changes, firstly the original Copenhagen 2025 climate plan is examined. It is an illustrative example to see whether digital tools are used as a policy instrument and thus answer the first sub-research question: *To what extent does digitalization determine the policy instruments in the Climate Plan of Copenhagen to become carbon neutral by 2025?* (5.1.1). This is done by initially identifying the used policy instruments and then examining why some were frequently or rarely used.

A first look at the Copenhagen Climate Plan shows that it uses a wide range of initiatives and policy instruments to achieve the climate goal of becoming carbon neutral by 2025 (Copenhagen, 2012). This becomes particularly evident by a quantification of the content analysis. A total of 33 policy initiatives were detected in the coding (Figure 4). These initiatives are divided into four sectors: energy consumption, energy production, green mobility, and city administration initiatives (Copenhagen, 2012, 2017, 2020). With just under half of all initiatives (~ 45,5%), the focus of the initiatives is largely on the area of energy consumption (Figure 4). Across those 33 initiatives, 61 policy instruments (Figure 5) were identified.

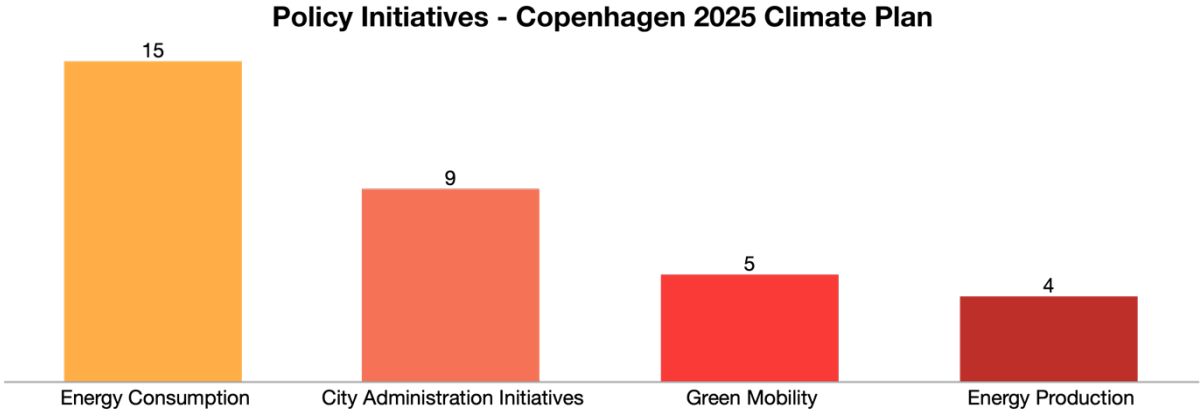

Figure 4. Frequency of policy initiatives in the Climate Plan – Copenhagen 2025.

Building on this, the extent and why digital instruments have been used in the Climate Plan of Copenhagen is examined to answer the second sub-question: *Why do we see digital instruments in the Climate Plan of Copenhagen?* (5.1.2).

5.1.1. To what extent does digitalization determine the policy instruments in the Climate Plan of Copenhagen to become carbon neutral by 2025?

The results of the content analysis are summarized in Figure 5, which depicts the frequency of the different policy instruments used in the Climate Plan of Copenhagen.

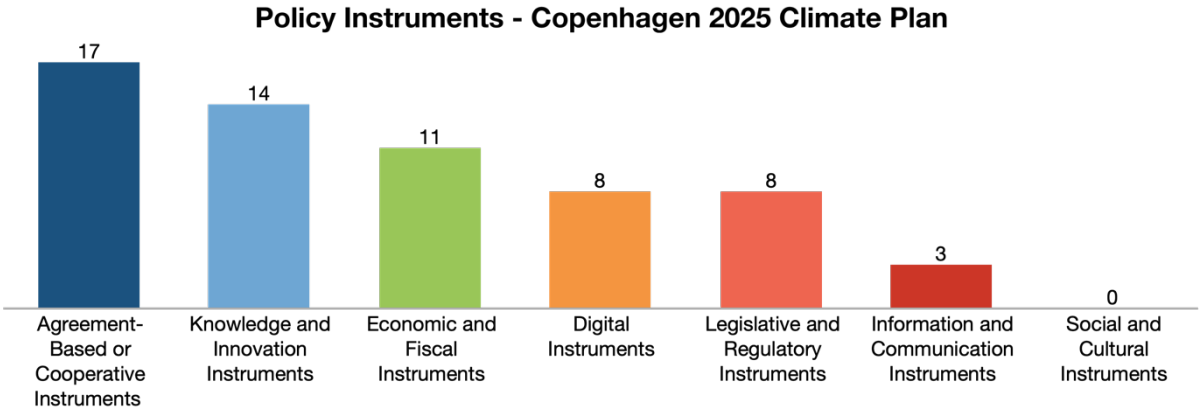

Figure 5. Frequency of policy instruments in the Climate Plan – Copenhagen 2025.

The *digital instruments* that are used in the Climate Plan of Copenhagen are of particular interest. Overall, eight policy instruments could be classified as *digital instruments* (Figure 5). They appear with the same frequency as legislative and regulatory instruments and are thus clearly represented in the strategy. Without the new classification as digital policy instruments, they could previously only be subsumed under knowledge and innovation instruments. However, the frequency of explicit digital measures indicates and underlines the assumption that digital tools should be defined as a policy instrument in their own entitlement. They offer the state/government the opportunity to influence the behavior of society directly and indirectly through simplified application, education, information, and more efficient systems (B. George & Paul, 2020). It is noticeable that in the Climate Plan of Copenhagen, digital instruments are mostly used as supporting instrument in an initiative and are mainly found in the area of energy consumption initiatives. The energy consumption initiatives 'Efficient Heat and Domestic Water Supplies', 'Digital Infrastructure', 'The smart building and Flexible Consumption and Smart Grid' rely not only on digital instruments, but also on additional instruments (Copenhagen, 2012). Most of these are knowledge and information as well as agreement-based or cooperative instruments. This indicates that the city of Copenhagen cannot implement these digital solutions as a sole instrument and that information gathering is often an important aspect of achieving or designing more sustainable urban solutions. This observation is also found in the Green Mobility initiative, which uses digital tools: Intelligent Traffic control and eco-monitoring (Copenhagen, 2012). In addition to digital instruments, as a traffic management system that relies on real time data and eco-monitoring, this initiative also uses knowledge and information and agreement-based or cooperative instruments (Copenhagen, 2012). The 'Consumption Mapping and Energy Management' initiative in the area of City Administration also does

not exclusively use the digital instrument, a remote meter reading of public administration buildings. Since these "energy consumption management and energy-efficient operations contain a huge energy saving potential" (Copenhagen, 2012, p. 51), the existing municipal Energy Savings Fund should support proposals to this area. Thus, the initiative is additionally using an economic and fiscal instrument.

In the comparison of the used policy instruments, the *agreement-based or cooperative instruments* are clearly the most frequently used (they are used 17 times). This observation seems reasonable given the fact that the City of Copenhagen does not have all the resources and know-how to achieve its ambitious climate targets on its own. For instance, the digital policy instruments were often used together with agreement-based or cooperative instruments. The city of Copenhagen is dependent on partners from research and business, the implementation of citizens, as well as the cooperation of other public actors (Mortensen, 2013). This is verified by looking at the actors mentioned in the different initiatives. The City of Copenhagen names itself most often as an actor in its initiatives, yet in many initiatives it does not plan to act alone. Rather, it relies on cooperation with other public actors or external partners such as companies. These are to provide support in implementation and development. It is striking that there is no cooperation with private citizens who, for example in the case of digital instruments, in many cases are the users of the developed digital solutions (Figure 6).

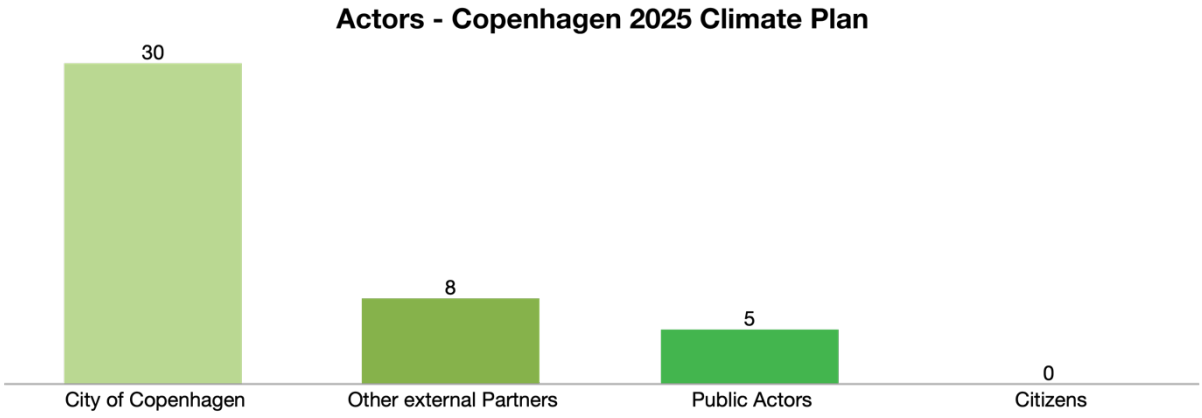

Figure 6. Frequency of Actors in the Climate Plan - Copenhagen 2025.

Knowledge and innovation instruments were used 14 times (Figure 5). This can also be explained by the fact that the City of Copenhagen does not currently have all the knowledge and know-how to achieve the climate targets (Goulder & Parry, 2008). To a greater degree, it is necessary to continue to generate knowledge and, building on this, to develop innovative measures and technologies on how carbon consumption in urban areas can be drastically reduced without restricting the quality of life of the population, but in the best scenario even improving it at the same time.

Economic and fiscal instruments were also used frequently (11 times). The frequency of these codes shines a light on the relation of these instruments. For the development of new technologies and measures, financing of research and development is necessary. In addition, *economic and fiscal*

instruments offer the possibility of creating incentives that provoke certain behavior through subsidies and other financial relief for private individuals or companies (Bouwma et al., 2015).

Legislative and regulatory instruments are also classic instruments of administrative action. They can directly control the behavior of citizens through regulations, laws and prohibitions and thus offer a good opportunity to achieve public authority goals (Bouwma et al., 2015). However, they also have disadvantages and are particularly difficult to implement, as new laws or regulations must be enacted properly, which in turn results in a high political and administrative burden. In short, a policy idea is not easily turned into a legislative or regulatory instrument (Makse & Volden, 2001). Furthermore, environmental policies face "information problems faced by regulators as well as limitations in the ability of these instruments to optimally engage the various channels for emissions reductions." (Goulder & Parry, 2008, p. 157). This explains the observation that the City of Copenhagen uses them to achieve climate goals, but not primarily (eight times) (Figure 5).

Rarely used are *direct information and communication instruments* by the state/government to influence the education of the population. *Social and cultural instruments* are not used at all (Figure 5). Both instruments, in contrast to the other (used) instruments of the Climate Plan, indicate to be government-centered and not citizen-centered. Government-centered policies are traditional governing through local authorities (Barnes et al., 2008). While those are made by the government for the people, citizen-centered policies offer local people and services the opportunity to participate in policy choices, as well as allocate resources (Barnes et al., 2008). Direct information and communication instruments aim to inform the population unilaterally through the government. Social and cultural instruments can also be unilaterally designed by the government in a way that they do not allow the affected social and cultural groups to participate in the development process and only offer them a 'finished result'. Overall, the Climate Plan of Copenhagen shows a clear orientation towards technological innovations to achieve the climate goals, which are partly shaped by digital tools. Due to the current lack of knowledge and resources, this innovation approach is only to achieve through cooperation with other actors and by the implementation through the citizens. These results indicate that the Climate Plan Copenhagen is designed rather citizen-centered. This is also particularly evident in the frequency of which the City of Copenhagen plans its initiatives with external partners (Figure 6). This could explain the significantly more restrained use of government-centered instruments. However, it contrasts with the observation that in the Climate Plan itself, no cooperation with citizens is directly planned (Figure 6). Copenhagen relies solely on other public actors and external partners. Despite the citizen-centered orientation of the Climate Plan, citizens themselves do not participate in the development and shaping of the initiatives. This suggests that they are seen more as end users or customers of the climate initiatives. This could be problematic, as it makes it difficult to ensure that citizens value and therefore implement digital

measures. Research has shown that there is a correlation between citizen satisfaction and the degree of digitalization in the public sector (Bernhard, Norström, Snis, Gråsjö, & Gellerstedt, 2018).

This innovation approach of the Climate Plan of Copenhagen is also reflected in the consideration of the different *policy areas*, which provide a better understanding of the contexts in which policy initiatives and instruments are motivated. Innovation was by far the most frequently identified policy area, but *digital*, *research* and *technical* were also among the coded areas. The frequency of the *political* and *economic* areas can be explained by the fact that the measures must be implemented politically and economically. Once again, it is evident that areas such as *social*, *cultural* and *education* are hardly used or not used at all (Figure 7).

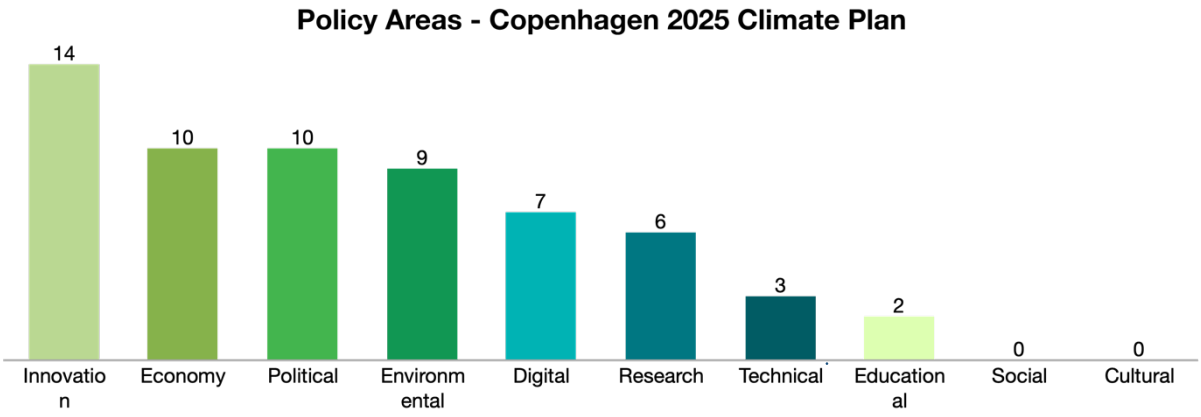

Figure 7. Frequency of policy areas in the Climate Plan – Copenhagen 2025.

Altogether, it has become clear that digital instruments have been included in the policy paper to reach the Copenhagen climate goals. Although digital instruments do not play the most important role, they are clearly represented as supportive instruments. Overall, the role of digital instruments can be summarized as a clear and important factor.

5.1.2. Why do we see digital policy instruments in the Climate Plan of Copenhagen?

The question of how governments choose policy instruments has already been examined in a lot of studies and research (Borrás & Edquist, 2013; Goulder & Parry, 2008; Howlett & Ramesh, 1993; Schneider & Ingram, 1990). Against this background, this section will examine the question: *Why do we see digital policy instruments in the Climate Plan of Copenhagen?*

In this thesis, digital instruments are understood as instruments influencing the behavior of the population through the possibilities offered by digitalization (see Table 2, p. 11). The use of digital instruments enables both technical and civic innovation through their application (Schou & Hjelholt, 2018). This target of (technical/digital) innovation could be identified in the Climate Plan of the City of Copenhagen (5.1.1). The investigation of why we see digital instruments in the Climate Plan of

Copenhagen is thus based on Rogers (2004) attribute typology, which defines five attributes of innovation that predict their adoption rate: *relative advantage*, *compatibility*, *complexity*, *observability* and *trialability*.

Rogers defines *relative advantage* as "the degree to which innovation is perceived as being better than the idea it supersedes. … [It is] a ratio of expected benefits and costs of adoption" (Rogers, 2004, p. 212). The digital policy instruments used, such as smart grids, smart buildings and a smart traffic management system (Copenhagen, 2012), represent a relative high advantage overall. From the perspective of the City of Copenhagen, they represent a great potential in terms of their expected benefits. For example, they state that "[a]ccess to public energy consumption data creates a scope for new services and new information for the benefit of both Copenhageners and businesses." (Copenhagen, 2012, p. 34). This results in a net gain by using these instruments as they state that "[t]he [climate] plan requires investments. But the climate plan documents that they will pay for themselves both with regard to the climate, the environment and the health of Copenhageners as well as the economy." (Copenhagen, 2012, p. 4). The digital instruments are also classified as compatible. *Compatibility* is defined as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2004, p. 224). The use of digitalization in the planned measures offers both the user and the provider more efficient solutions. Existing solutions can be complemented by digital solutions, thereby increasing their efficiency and sustainability. The planned smartification of the municipal buildings is a particularly good example here. The digitalization of water and heating meters can help to observe trends and „[t]he improved master data will make it easier to optimize operations" (Copenhagen, 2012, p. 51). Furthermore, the planned digital instruments do not appear to be too complex and are therefore easy to implement. *Complexity* is "the degree to which an innovation is perceived as relatively difficult understand and use" (Rogers, 2004, p. 242). The smart traffic management system, for example, is intended to make traffic light control intelligent, which is implemented through current traffic data, thus preventing traffic jams and making bicycling more attractive (Copenhagen, 2012). Moreover, digital instruments are easy to overserve and test, due to the fact that they enable solutions which all citizens can use. *Observability* is "the degree to which results of an innovation are visible to others" (Rogers, 2004, p. 244). Lastly *trialability* is "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2004, p. 243). This is also reflected in the Climate Plan of Copenhagen. For example, the concept of smart buildings will initially be tested in two buildings of the city administration "before it will spread to various sectors in Copenhagen" (Copenhagen, 2012, p. 34). At the same time, the digital instruments are always observable, because they offer applications that are used by the population, e.g. the smart traffic management system. Thus, they also fulfill the attributes of observability and trialability.

This examination of the identified digital policy instruments regarding the five innovation attributes of Rogers (2004) emphasizes that digital instruments are very innovation friendly and supportive. Consequently, they fit very well into a Climate Plan based on innovation.

5.2. Classification of digital policy instruments

As it has become clear that the City of Copenhagen also relies on digital policy instruments in its policy innovations to achieve its climate goals, the digital policy instruments are examined in more detail. In this context, the sub-research question: *How can the digital policy instruments in the Sustainability Strategy of Copenhagen be classified?* will be answered. For this purpose, not only the original Climate Plan, but also the roadmaps 2017-2020 and 2021-2025 were examined in greater detail. A total of 16 digital policy instruments were identified and analyzed regarding their similarities and differences (Table 1).

	Energy Consumption	**Energy Production**	**Green Mobility**	**Public Administration Initiatives**	**Σ**
Digital Instruments	5	0	7	4	16

Table 3. Frequency of digital policy instruments used in the policy initiatives of the Sustainability Strategy.

Digital policy instruments can be found in all policy documents of the Sustainability Strategy. They solely focus on energy consumption and public administration initiatives as well as green mobility, which obtains a slight emphasis among the others. There are no planned digital measures in the area of energy production (Table 3). The Danish energy supply is not only in public hands. Private actors, such as Ørsted, which have the know-how of energy production, are a big energy supplier in Denmark (Ørsted, 2021). As energy supply is crucial for society and has at the same time to fulfill high demands due to new climate policy targets, the energy sector is an already highly regulated sector in Denmark (The Danish Energy Agency, 2021). Additionally, energy supply is technically highly complex. This high complexity and the lack of knowledge regarding its potential as well as the risks of digital solutions in energy production might explain why Copenhagen does not plan to use digital instruments in energy production initiatives.

When analyzing the digital instruments used in the Copenhagen Sustainability Strategy in greater detail, it quickly becomes evident that they are based on different motivations and pursue different goals. Based on these different motivations and objectives, five different types of digital policy instruments are defined: *Information*, *Technology*, *Analysis*, *Efficiency gains* and *Flexibility* (Table 5). However, there are overlapping's in the categories, as some digital instruments have multiple motivations or goals. Therefore, multiple coding per instrument is possible.

	Energy Consumption	Energy Production	Green Mobility	Public Administration Initiatives	Σ
information-based digital policy instruments	2	-	1	-	3
technology-based digital policy instruments	3	-	2	-	5
analysis-based digital policy instruments	1	-	1	4	6
efficiency gain based digital policy instruments	3	-	-	1	4
flexibility-based policy instruments	3	-	-	1	4

Table 4. Detailed frequency of the different digital policy instrument types used in the policy initiatives of the Sustainability Strategy.

Information-based digital policy instruments are to be understood as those whose aim is to provide information and thereby create the greatest possible transparency. Thus, the behavior of citizens shall be influenced by enabling informed decisions based on precise and multifaceted information. Such instruments were identified in the original Climate Plan as well as in the roadmap 2017-2020. They were used in the policy initiatives of green mobility and energy consumption. The fact that they are not found in public administration initiatives (Table 4) could be explained against the background that they are intended to inform of citizens. The concrete objectives are, for example, to provide access to real-time data on electricity and heat (Copenhagen, 2016) or to create a digital platform linking all available means of transport such as trains, buses, metro, but also car-sharing, public bicycles and taxis (Copenhagen, 2016). On the other hand, this lack of information-based tools could be a shortcoming in public administration digital initiatives, as digital measures in the administrative sector are comparatively new. They might need more accurate information to be more precise, better and more user-friendly. This would promote better and faster implementation. On the other hand, this is countered by the fact that Denmark in particular already has a highly digitized public sector in comparison to the rest of Europe and has already begun this digitization at an early stage (European Commission, 2020b; Scupola, 2019). Whether the public sector is actually insufficiently informed would have to be investigated by further research.

Instead, *technology-based digital policy instruments* are those that aim at technical development or improvement of existing technical devices. In this case, the behavior of the population is to be influenced solely through technical development and further training of digital solutions. They could also be identified in initiatives of green mobility and energy consumption (Table 4). In the area of green mobility, the roadmap 2017-2020 foresees intelligent traffic control, prioritizing buses and green waves for bicycles. This prioritization in traffic makes the environmentally harmful traffic of cars less attractive and thereby bicycling and public transport more attractive through faster travel times. Additionally,

multimodal stations of public bicycles, bicycling parking and car-sharing are planned which shall have among others online information systems and public toilets (Copenhagen, 2016).

Furthermore, *analysis-based digital policy instruments* are characterized by the fact that information is to be collected and analyzed through digital solutions. The information gained through big data and the resulting data generation and analysis shall be used to create technically more efficient, more flexible and more individualized solutions as well as to make more informed policy decisions. For example, the water and heating will be read remotely to identify trends and take any necessary changes and measures (Copenhagen, 2012, 2016). Furthermore, traffic data will be monitored to develop a traffic management system based on the analysis of this data (Copenhagen, 2012, 2016). Data is also to be collected and analyzed for new buildings in order to follow up on "whether the buildings meet the requirements stipulated by the city in the tenders." (Copenhagen, 2020, p. 49).

In contrast, *efficiency gain based digital policy instruments* and *flexibility-based policy instruments* are not characterized by focusing primarily on changing people's behavior. On the one hand efficiency gain-based digital policy instruments are characterized by their focus on increasing the efficiency of existing systems. Their overall goal is to make the systems used by citizens more efficiently so that they accomplish more and consume fewer resources. On the other hand, flexibility-based policy instruments aim to make existing systems or systems under development more flexible so that they can respond to variations in citizens' usage patterns. The flexibility that digital solutions enable is not only intended to maintain and improve living standards, but also to be implemented as efficiently as possible in technical terms. These two instruments can be found in the policy documents but, with one exception in each case, they focus on the original climate plan. It is striking that they are mostly coded overlapping and are only found in energy consumption initiatives. This suggests that they complement each other very well or cannot be distinguished clearly. Both are focused on purely technical aspects of digital solutions in the energy consumption sector. The initiatives there mostly aim to develop digital solutions that both create greater energy efficiency and can react to fluctuations in the grid. For example, 'smart buildings' are planned and the City of Copenhagen itself states that "smart building is a concept involving a number of elements within the field of energy efficiency, flexibility and energy management" (Copenhagen, 2012, p. 34). Thus, they are striving for a digital solution that on the one hand provides more efficiency and on the other hand can react to fluctuations. These are different goals and capabilities that a digital system must have. Nevertheless, they complement each other very well in terms of application and can therefore hardly be separated from each other.

All these different types of digital policy instruments are summarized in the table below.

	definition	example
information*	digital solutions, that provide information and thereby aim to create the greatest possible transparency for the citizens	digital platforms, e.g., access to public energy consumption data
technology*	digital solutions, that improve existing technical devices or services or develop new	intelligent traffic control, smart grids
analysis*	digital solutions, that collect and analyze big data to create technically more efficient, more flexible, and more individualized solutions as well as to make more informed policy decisions	remote water and heating meters
efficiency gains*	digital solutions, that make the systems that people use more efficient to improve performance and use fewer resources.	intelligent car recharging
flexibility*	digital solutions, that make existing systems or systems to be developed more flexible, so that they can react to fluctuations in the behavior of citizens in their use.	smart buildings, intelligent energy management systems

Table 5. Classification of digital policy instruments.

* Authors own classification and definition.

5.3. Barriers of Digitalization

The advantages and disadvantages of digitalization are a recurring aspect not only in the digitalization debate, but also in the sustainability debate (Seele & Lock, 2017). To name just a few aspects in the public sector, digitalization offers an increase in the efficiency, a decrease of costs, greater transparency of government actions and improvement in client service (Aliee Fereidoon, 2019; Anthony Jnr, 2021; Del Río Castro et al., 2021). Disadvantageous aspects that are frequently discussed are new security risks associated with digitization, such as data protection (Svensson, Rosengren, & Åström, 2016), especially of personal data, as well as the increasing demand for electricity and server capacities, which have a negative impact on climate protection (Morley et al., 2018). Against the background of the advantages and disadvantages that urban digital transformation can offer, it is particularly questionable which factors are barriers for an implementation. By examining such barriers, the sub-question *How can the degree of usage of digital policy instruments in Copenhagen's Sustainability Strategy be explained?* will be answered.

A total of 16 digital policy instruments were identified in the Copenhagen Sustainability Strategy (Table 3, p. 19). Digital policy instruments are thus clearly represented, but not dominantly used (5.1.1). The increased use of digital policy instruments could be explained by a transformation of urban sustainability governance in order to achieve urban sustainability. This is a steady but not straightforward process (Rosenzweig & Solecki, 2018). As discussed, the diffusion of such innovations depends on various factors (5.1.2). Furthermore, certain barriers can hinder the adoption of innovations, especially digital policy instruments. Mondschein et al. (2021) assume that the greatest challenges policymakers face in the use of digital technologies are organizational or technological in nature. Organizational barriers tend to have a greater significance and include, among others, different goals of the stakeholders or conflicts with already existing operational practices and organizational structures. In contrast, technological barriers can, for example, include outdated infrastructure (Mondschein et al., 2021). They state that this non-technical dimension is underrepresented in the research about smart city development. When looking at the Copenhagen Sustainability Strategy, it is noticeable that it refers to technical innovations in particular. The sustainability goals are to be achieved primarily through innovative initiatives and cooperation (Figure 4 and Figure 7) with external partners as well as other public partners (Figure 6). This focus on citizen-centric policy instruments, i.e. on cooperation with other parties (even if the citizens themselves are not involved), suggests that the City of Copenhagen rather focuses on overcoming technical barriers. These are to be overcome by emphasizing cooperation. The strategy does not discuss that possible organizational structures could complicate the implementation of digital policy instruments or how they could be overcome. However, it is also striking here that the citizens themselves are not integrated into the process. On the one hand, this indicates that they are seen purely as 'users' of the developed products. On the other hand, this could also indicate that the City of Copenhagen shies away from the complicated process of integrating citizens into development processes. This suggests that the shift out of the 'comfort zone', i.e. the existing organizational structures, towards more citizen participation is avoided. Thus, there are organizational barriers to the implementation of digitalization here as well. These are not addressed in the Copenhagen Sustainability Strategy. This concentration does not seem surprising given the fact that technical barriers are easier to overcome than organizational ones (Mondschein et al., 2021).

Veselitskaya et al. (2019), on the other hand, consider other aspects regarding possible barriers to implementation: the actors who are involved in urban planning, how the principles of urban planning of a municipality are designed and what mechanisms for implementing public-private partnerships exist (Veselitskaya et al., 2019). Considering these aspects, the first thing that stands out is that the Copenhagen Sustainability Strategy clearly focuses on using and expanding public-private partnerships. Many of the planned initiatives rely on cooperation with other external partners who bring certain know-how or resources (5.1). This is particularly evident in the fact that the most frequently used policy instrument is cooperation (Figure 5). In this way, the City of Copenhagen recognizes a potential barrier to

implementation and takes sure to reduce it as much as possible. In addition, the top priority of this Sustainability Strategy is environmental protection. The urban planning of the city of Copenhagen, however, tries to achieve this with a wide variety of policy instruments and relies, for example, on the development of infrastructure and innovative solutions. At the same time, the Copenhagen Sustainability Strategy aims to secure the standard of living of citizens and urban development through the implementation of new technologies (Copenhagen, 2012). Hence, it is not planned unilaterally, but uses different channels and thus has a higher probability of being well implemented. Regarding the actors in urban planning, it must again be noted that the citizens themselves are not involved. The City of Copenhagen relies solely on other public actors and external partners also for later cooperation. This can be a barrier in the later implementation of the measures and is consequently misjudged by the City of Copenhagen in its planning.

Thus, the non-involvement of citizens in the development and design process of digital policies, is a potential barrier in the implementation of digital policy instruments, both in terms of organizational aspects and in terms of the actors in urban planning. Overall, it appears that the used digital policy instruments are in line with the chosen innovative approach of the Copenhagen Sustainability Strategy. The clear barriers to implementation could explain the fact that they are clearly visible and used in the policy papers, but not dominant, even though digitalization is often perceived to offer sustainability potential (G. George et al., 2020). The organizational barriers to concretely involving citizens in the development process are high, because it requires a lot of effort. However, citizens are ultimately the ones who must adopt the measures. Consequently, their participation has the potential for higher reception.

6. Conclusion

In light of the fact that the public administration has to cope simultaneously with the great challenges posed by the advancing digitalization and the challenges posed by climate change, this thesis used an exemplary case to investigate whether digitalization can promote urban sustainability transformations. For this purpose, the Copenhagen Sustainability Strategy, consisting of the Copenhagen Climate Plan together with the two associated roadmaps, which aim to achieve carbon neutrality by 2025, were examined. The examination has shown that the Climate Plan of Copenhagen is primarily based on the idea of innovation. Thus, the goal of carbon neutrality by 2025 is to be achieved through technical and digital innovations (5.1). This thesis set out to investigate whether digitalization can promote urban sustainability transformations. The investigation of the Copenhagen Sustainability Strategy has shown that digital measures are used to achieve climate goals. Thus, digitalization offers potential that can be used in the transformation of sustainable urban governance.

In this regard, this thesis put forward that there are digital policy instruments with which the state can influence the behavior of its citizens. Such digital policy instruments could also be identified

in the Climate Plan of Copenhagen and the associated roadmaps. A closer look at the policy instruments used in the Climate Plan revealed that digital instruments were clearly used, namely eight times (5.1.1). This was confirmed when looking at the Sustainability Strategy as a whole. In total, 16 digital policy instruments were identified throughout the Sustainability Strategy (5.2). Thus, the usage is significant, but not dominant. Based on this, it was investigated why digital instruments can be found in the Climate Plan of Copenhagen. The identified digital policy instruments were examined in detail by using the attribute typology for innovation developed by Rogers (2004). The findings suggest that that digital policy instruments are very innovative. Therefore, it can be said that they represent a good opportunity for the administration to act, especially in the case of policy initiatives that are designed for innovation (5.1.2). A closer examination of the digital policy instruments used in the Sustainability Strategy revealed that they are based on different motivations and pursue different goals. Based on this, a classification of digital policy instruments was developed. The types of *information*, *technology*, *analysis*, *efficiency* and *Flexibility* were identified and defined (5.2). Efficiency gain-based digital policy instruments and flexibility-based policy instruments differ significantly from the other digital policy instruments because they do not primarily focus on changing citizens' behavior. Their overarching goal is to make the systems used by citizens more efficient so that they do more and consume fewer resources. Hence, their focus is clearly on the (existing) digital systems. There were no major differences in the frequency of usage of people-centered or technology-centered digital policy tools. However, it should be mentioned that both technology-centered digital policy instruments were only used together. In addition, the question of how the obvious but not dominant usage of digital policy instruments in the Copenhagen Sustainability Strategy can be explained was examined. For this purpose, the research of Mondschein et al. (2021) and the study by Veselitskaya et al. (2019) investigating the barriers to the implementation of digital solutions were used. It has been shown that the lack of direct cooperation by the City of Copenhagen with its citizens can be an obstacle in the later implementation of the digital solutions. This is because the citizens are in many cases the users and implementers of these. This aspect thus reflects an organizational barrier (Mondschein et al., 2021), because working directly with citizens on policies is costly and not the usual state-centered governance. Against the background of Veselitskaya et al. (2019) research, the lack of integration of citizens in the development and implementation process is also a barrier to the implementation of digital solutions. Thus, this thesis concludes that although digitalization possibly offers great sustainability potential, the fact that they are clearly used in the policy papers, can be explained by the clear barriers to implementation (5.3).

Overall, a new policy instrument – digital instruments – could be identified, which makes it possible to influence the behavior of citizens just like other policy instruments. It can therefore be assumed that digital instruments and thus digitalization can also promote urban sustainability.

6.1. Research Agenda

As this thesis is based on the investigation of a single case study, the results are to be understood as indicative. Thus, the findings also signalize that much more work is needed in this area, which is why this thesis concludes by pointing out three possible directions of research.

Firstly, other studies should investigate whether digital policy instruments are used in other sustainability strategies or actual measures for urban sustainability. Since this work can only state that digitalization and the resulting opportunities, such as digital policy instruments, can in theory promote urban sustainability transformations, it must be further investigated how great this potential is. A focus should be placed on weighing the advantages and disadvantages of digital policy instruments, as that was an unconsidered aspect of the examined Sustainability Strategy.

Secondly, the classification of digital policy instruments developed in this thesis should be verified by further research. In this context, other digital policy instruments should be used to examine whether the classifications identified in this thesis can be transferred. In addition, it should be investigated whether further classifications can be identified or whether the classifications defined in this thesis are too narrow.

The last aspect to be examined in more detail is the question of barriers to the implementation of digital solutions when it comes to urban sustainability strategies. Not only should the barriers be examined more closely, but also the possibilities for public administration to overcome them. As this thesis has shown, it would be a particularly interesting aspect in this context to examine how different actors play a role in enabling or representing barriers.

6.2. Limitations and Outlook

The biggest limitation of this thesis is at the same time its biggest strength. The fact that this thesis was conducted as a single case study examining the Sustainability Strategy of Copenhagen facilitated an in-depth analysis. At the same time, this enabled to identify aspects, which may have an importance also in other cases. Thus, this qualitative single case study based on a content analysis gives the possibility to observe aspects and develop assumptions based on them. Thus, it enables theory developing.
Withal, this also means that the results of this thesis cannot be generalized. They come from the investigation of a single case study. They can therefore only be an indicator of phenomena but must be verified by further research and case studies.

Another limitation of this study is the chosen research method of content analysis, as it is based exclusively on the study of the policy documents. With a longer research period and a research budget, surveys and interviews could have been conducted that would have provided different insights. This

would have made it possible, for example, to investigate whether the non-use of information-based digital policy instruments is actually a shortcoming (5.2) by investigating whether the public administration actually has too little information to make good policies.

Overall, this thesis shows that there is a growing need for further research on the interplay between the challenges of climate change and digitalization in an urban context. The results of the conducted case study of this thesis also need to be confirmed and extended by other research methods. In particular, the involvement of citizens in the creation and development process of digital policy instruments could be an important step for a progressive implementation. Thus, the results of this case study thus provide a good starting point for further research. However, as the interplay of these challenges in the urban context has been little explored so far, further research must also address fundamental questions such as:

Is the use of digital policy instruments a lasting factor in the achievement of climate goals or rather a trend whose negative aspects are not considered?

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8. List of tables

9. List of figures

10. List of examined policy papers

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