# Building Climate Resilience in Smart Cities Using Open Data Services

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## Abstract

*Climate change and its consequences are among modern societies' most critical challenges. To that end, cities have focused on using information technology in their climate mitigation efforts in smart cities. Considering the magnitude of the problem and its impact on our societies, the need for building climate-resilient smart cities is crucial. In this study, we aim to understand how smart cities can achieve climate resilience. Conducting an exploratory field study and using the urban climate resilience framework as a theoretical lens, we suggest that smart cities can leverage the potential of open data and citizen engagement to reach climate resilience. In particular, our results show that building climate-resilient cities requires structural changes in citizen engagement processes and climate considerations. To that end, open data services and tools can be used to improve citizen engagement processes and develop more sustainable smart city solutions.*

**Keywords:** Smart city, Smart sustainable city, Open data, Sustainability, Climate resilience.

## 1. Introduction

Climate change and its consequences are critical challenges we face in modern societies. Intensified rainfall, droughts, sea-level rise, and poor air quality have tremendous social, environmental, and financial costs for societies. We have entered a new geological period, the "Anthropocene", in which human activities impact the earth on a scale relatable to that of a force of nature (Urry, 2015). Climate change has tangible impacts on how we live and how our cities operate in the coming decades. Thus, it is crucial that we "climate-proof" our cities and societies against the drastic consequences of climate change.

Until now, smart cities have mainly focused on using ICT and digital services to improve the functionality of urban life (Bibri, 2019; Caragliu and Nijkamp, 2009; Meriläinen et al., 2022; Yigitcanlar et al., 2018). Moreover, the term and language of the "smart city" have been criticized as being used to attract economic and political capital without making significant changes otherwise (Sterling, 2018). There is a growing trend of emphasizing positive traits (e.g., technological advancements, business-friendliness) in cities for promotional purposes while simultaneously downplaying negative ones such as pollution and waste (Hollands, 2008). As a result, in the past, research and activism have focused on climate mitigation efforts. However, forerunners in the smart city dominion have started to focus also on climate adaptation. For example, the City of Barcelona has implemented a network of Storm Water Tanks controlled remotely by ICT systems, reducing urban flooding likelihood by 75 percent and operational costs by 30 percent (Fernández & Peek, 2020).

We argue that climate adaptation is just as important as climate change mitigation for smart cities. We need to make our smart cities climate-resilient, but in the process, we must also mitigate the actual consequences of climate change (Fernández & Peek, 2020). In this study, we aim to show that smart cities must incorporate sustainability and climate resilience at every level. We suggest that these smart sustainable cities must combine the best of human and technology capabilities to reach climate resilience. On the one hand, empowering citizens to participate in urban development enables cities to capture citizens' concerns and ideas about climate change. On the other hand, using modern technologies enable cities to constantly gather data from urban environments to identify ecological and social issues. These two data sources can be combined to identify and address the most urgent climate issues a city faces. This, in turn, could empower smart cities to maintain climate resilience.

To the best of our knowledge, information systems (IS) literature lacks studies on climate resilience in smart cities. We posit that open data solutions (e.g., clear digital communication channels between the city and its citizens, participatory mapping and budgeting, crowdsourcing) can be used to bridge the gap between cities and citizens to build

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and maintain climate resilience in smart cities. Thus, we seek to answer the following question:

*How can open data be used to engage citizens in building climate resilience in smart cities?*

To address this question, we have conducted an exploratory field study. We conducted semi-structured interviews with smart city professionals and analyzed the collected data using thematic analysis. Our results show that for building climate-resilient smart cities, there is a need for structural changes in citizen engagement processes as well as climate considerations and sustainable solutions. We demonstrate how open data has the potential to interlink these elements and enable cities to develop more sustainable smart city solutions.

## 2. Research Background

### 2.1. Sustainability in smart cities

As the climate change impacts become more intense, diverse, and unpredictable, cities inevitably grow more vulnerable to them. According to Hunt & Watkiss (2011), resource availability, water supply, infrastructure, energy production and usage, and general health, among others, will severely be impacted by climate change, and on a city level, air quality, biodiversity, cultural heritage, and tourism will also be dealt a devastating blow. To minimize these consequences, cities should strive to adapt to this climatic change to create a more suitable and pleasant environment for living. As highlighted by Fernández and Peek (2020, P.512), *"the need to create adaptive societies is more crucial than ever."*

With population growth and rural populations flocking to cities, urban environments must be able to accommodate more people. As the population grows, so will the accumulation of waste and resource consumption. Cities "account for 60-80 percent of global greenhouse gas emissions, 50 percent of global waste, and 75 percent of global natural resource consumption" (United Nations Environment Programme, 2013).

Previous studies on smart city planning (e.g., Townsend & Lorimer, 2015) barely mention the global issue of climate change or a need for a climate adaptation strategy; the emphasis is instead put on technological advancement. The environmental discourse in the smart city realm is included due to its trendiness but is often overshadowed by the discourse of economic growth (Joss et al., 2019). Thus, many aspects of sustainability, such as biodiversity, are ignored or left out of the environmental segment of smart cities, which tend to favor climate and energy (Joss et al., 2019). However, recent research and practice show increasing attention to addressing environmental sustainability in smart cities (de Azambuja et al., 2020; Höjer & Wangel, 2014; Meriläinen et al., 2022).

### 2.2. Citizen engagement

One dimension of city smartness is collective intelligence, meaning that a group of heterogenous citizens collaborating on a platform is generally more likely to provide smarter solutions than one expert (Anttiroiko, 2016). Therefore, involving citizens openly in planning, decision making, and governance and harnessing their potential could play an essential role in governing the smart city.

There are many marginalized but incredibly talented individuals, movements, and organizations that could provide radically new ideas to improve cities. To accomplish this, cities should focus on fostering smart communities by enabling interaction between systems and people and empowering citizens, especially marginalized groups, to get involved in developing their cities (Bolívar & Meijer, 2016; Paquet, 2001). Open data systems have the potential to play a crucial role in this type of collaboration.

Smart cities should strive for open governance, which would add transparency to city councils and encourage active participation of citizens to collaborate in the city's decision-making processes, thereby increasing trust between citizens and the government (Casini, 2017). *Open Ahjo*, an interface that catalogs and provides access to documents on the city of Helsinki, is a good example of open governance initiatives (Anttiroiko, 2016). According to Anttiroiko (2016), citizens are involved in different roles, and their involvement serves different purposes and functions; some initiatives grant citizens a voice, some solidify their rights as political actors, and others as service users who provide valuable data and feedback. This, of course, requires trust between governments and citizens, which can be achieved by guaranteeing the privacy of citizens' data. Collaboration and shared decision-making between citizens and city councils bring forth the need for increased and careful data privacy and cyber security (Fernández & Peek, 2020).

### 2.3. Climate resilience

Climate resilience refers to "*a city's ability to reduce exposure and sensitivity to, and recover and learn from, gradual climatic changes or extreme climate events*" (Moraci et al., 2018, p.3). In other words, climate resilience is about adapting to climate issues and shocks. When it comes to climate adaptation in smart cities, there are no "one size fits

all" strategies. This is because each city is unique in terms of local and regional environmental issues it faces. However, one commonality exists: smart cities should position the environment at the core of their development and involve citizens and encourage their participation (Fernández & Peek, 2020).

Biesbroek et al. (2013) have identified the following barriers to climate change adaptation challenging: 1) The long-term impacts of climate change in contrast to the short-term nature of politics and decision-making, 2) the need to utilize scientific models to identify, understand and communicate the problem and propose solutions, and 3) the uncertain, vague and ambiguous nature of climate change. Moench & Tyler (2012) outline three actors in urban resilience: systems, agents, and institutions. However, these actors can also be a source of vulnerability if overlooked. They encapsulate the nature of vulnerability with the following statement: *"Vulnerability to climate change occurs when fragile, inflexible systems and/or marginalized or low-capacity agents are exposed to increased climate hazards, and their ability to respond or shift strategies is limited by constraining institutions" (*Moench & Tyler, 2012, P.318).

While assessing vulnerabilities in cities, it is important to keep in mind that focusing entirely on direct climate impacts leaves cities vulnerable to indirect effects, systemic weaknesses as well as constraints of the institutional dimension (Moench & Tyler, 2012). According to Sherbinin et al. (2007), when environmental stresses and shocks collide with shocks arising from society, regions face major consequences. Economic depression or social unrest reduces a system's capacity to cope with environmental issues (Sherbinin et al., 2007). Smart cities should analyze vulnerabilities, both systemic and infrastructural ones. This way, cities do not need to focus on specific threats but can instead focus on building overall resilience (Moench & Tyler, 2012). Even with high uncertainty, a climate resilience approach would be able to prepare a city well against climate threats (Moench & Tyler, 2012).

## 2.4. Open data

In short, open data is publicly disclosed, objectively factual data accrued through the execution of public services that can be accessed and used by anyone without any sort of restriction (Grimmelikhuijsen et al., 2017). Open data consists of various forms of data, including real-time and location-based data, medical data, reports, maps, satellite photographs, and pictures. Groups and roles of end-users of open data range from organizations, developers, citizens, activists, and NGOs (Grimmelikhuijsen et al., 2017; Lindman, Rossi & Tuunainen, 2013).

With the advent of smart cities, open data could provide a valuable tool to bridge the gap between cities and their citizens in governing the smart city, as well as creating value in the form of services, increasing government transparency, and enabling increased citizen participation in the processes and functions of the city. Open data is a main driver and component for creating new ideas and innovations (Bakici et al., 2013; Grimmelikhuijsen et al., 2017). These innovations range from business-driven innovations to innovations meant to co-produce public services with and initiated by citizens.

Spatial open data infrastructures are important for improving urban management, as the lack of reliable open data can negatively impact urban planning and implementation (Chakraborty et al., 2015). Furthermore, releasing open data is considered to strongly impact the level of citizens' participation. Public services created based on open data improve cooperation between citizens and governments and empower citizens to challenge the government, leading to political and social benefits (Grimmelikhuijsen et al., 2017; Janssen et al., 2012). Other benefits include improved big data analytics to create visualizations to understand complex datasets and to make more accurate predictions, impact analyses, and forecasts based on government data (Grimmelikhuijsen et al., 2017). Finally, releasing government data to the public presents a significant tool in the fight against corruption and the ineffective usage of public resources, as the absence of transparency and information asymmetry has the inherent risk of leading to corruption (Linders, 2013).

To summarize this section, inspired by the urban climate resilience framework proposed by Moench & Tyler (2012), we suggest that smart cities can leverage the potential of open data and citizen engagement to gain a deep understanding of climate vulnerabilities and ultimately build climate resilience. As shown in Figure 1, the framework comprises three main components: agents, systems, and institutions. Here, *systems* refer to interconnected entities that provide cities with different services, while *agents* are individuals and organizations in socio-ecological systems such as cities. *Institutions* govern how agents and systems interact with one another (Moench & Tyler, 2012). In light of the framework, we argue that open data services (i.e., systems) can facilitate communication and engagement between smart cities (i.e., institutions) and citizens (i.e., agents) to develop and use more sustainable urban solutions and ultimately achieve climate resilience in cities.

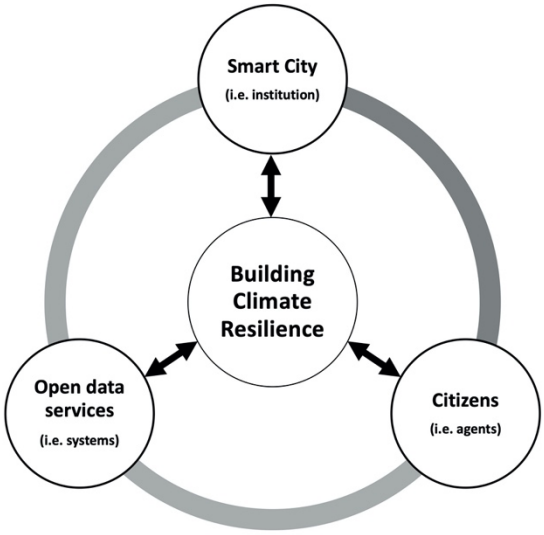


**Figure 1 Framework for urban climate resilience (adapted from Moench & Tyler, 2012)**

## 3. Methodology

Considering the novelty of the studied phenomenon (i.e., creating climate resilience in smart cities), we considered exploratory qualitative research a suitable approach. To that end, we decided to conduct a field study to understand how the application of open data could foster better and more effective citizen engagement to achieve sustainable transformations in cities and ultimately build climate resilience.

### 3.1. Data collection

We conducted seven semi-structured narrative interviews (Eriksson & Kovalainen, 2008) with smart city professionals from the City of Helsinki, Finland, between 2020-2021. The interviewees were identified through our professional networks. We tried to identify professionals from different sectors who work closely with various aspects of the research phenomena, including smart city, sustainability and climate change, and open data. Interview participants consisted of five males and two females, as well as two interview participants of non-Finnish backgrounds. Table 1 provides an overview of the interviewees' backgrounds.

The interviews were kept anonymous to encourage sharing more individualistic views and honest answers reflecting true beliefs and thought patterns. The interviews were conducted on Microsoft Teams and were video recorded. These recordings were then transcribed and imported into *ATLAS.ti* software for analysis.

**Table 1 Interviewees and their background**

| ID | Role | Sector | Background |
|---|---|---|---|
| I1 | Project Manager | Public | Urban development, green infrastructure initiatives. |
| I2 | Research Assistant | | Urban development tools for achieving carbon neutrality in cities. |
| I3 | Chief Sustainability Officer | Private | Orchestrating smart, safe, and sustainable cities with active citizen participation |
| I4 | Chief Executive Officer | | Consulting/ business development for sustainability and climate change. Advisor for a large non-profit climate network. |
| I5 | Development Director | NGO | Addressing environmental challenges in diverse, inclusive, and participatory ways on the grassroots level. |
| I6 | Researcher | Academia | Studying sustainability transformations, spatial planning for biodiversity, and social inclusion. |
| I7 | Researcher | | Studying open data usage in the smart city environment. |

The interview questions (see Appendix A) were open-ended and encouraged the participants to talk openly and from their points of view. At the same time, the interviewer acted as an activator and followed the norms of everyday conversation, such as active listening, as per the tradition of narrative research (Eriksson & Kovalainen, 2008). Considering the explorative nature of the research, the research questions evolved and changed as the research progressed. The literature highlights a lack of consensus about the definition of the smart city (e.g., Fernández & Peek, 2020; Hollands, 2008), and we asked the interviewees to describe their interpretations of the smart city concept. These definitions were not the main focus of this paper, but they provided a contextual background for analyzing each interview.

### 3.2. Data analysis

To analyze the collected data, we conducted a thematic analysis. The first author started by reading the interviewees one by one and conducting open coding. In the next step, similar and duplicate codes were merged, resulting in 120 open codes. These codes were then sorted into eight categories (i.e., sub-themes), reflecting three main themes: *citizen engagement*, *open data services*, and *smart sustainable cities* (see Figure 2).

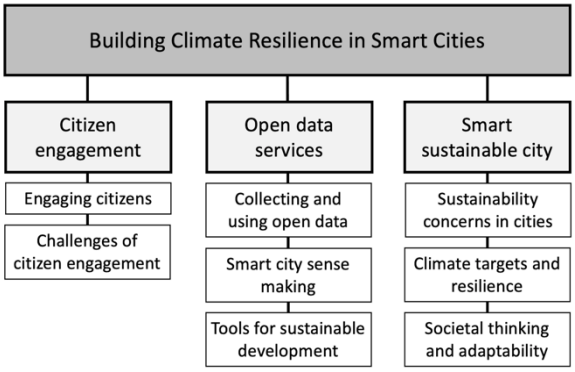


**Figure 2 Themes (grey) and sub-themes (white) emerged during the data analysis process.**

Several codes belong to more than one category, with usually one category being the primary one. This stage was very organic and iterative, and the analysis would alternate between coding for categories and themes and comparing codes within and between categories. The first author then would share and discuss the analysis results with other team members. Finally, the overarching theme "building climate resilience" was generated by examining the associations and relationships between the other three themes. This theme represents the factors needed to achieve climate resilience through citizen engagement and open data in smart sustainable cities.

## 4. Results

In this chapter, the results obtained from qualitative data analysis are summarized according to the themes generated during data analysis.

### 4.1. Citizen engagement

Almost all interviewees mentioned some form of crowdsourcing as an integral tool to integrate citizen participation in decision-making and planning in smart cities, be it hackathons, workshops, collaborative platforms, or participatory planning, mapping, or budgeting. These forms of participation enable two things: 1) the outsourcing of meaningful innovation to citizens and 2) meaningful engagement and listening, making citizens feel heard on issues that need improvement and change. The *Naturvation* project[1] (i.e., the Urban Nature Atlas) is a good example of a climate resilience participatory mapping initiative. The project provides a summary of different nature-based solutions, with reference examples on an interactive digital map, so the user can see where these solutions are taking place, what are their benefits and costs, and how different groups can engage with them in the future.

Our analysis shows that new technologies are not necessarily needed to make important improvements to a smart city regarding sustainability, climate resilience, and quality of life. Many issues are local and on a smaller scale, requiring incremental improvements, and thus not necessarily suitable for hackathons. For this reason, many interviewees listed having ***clear communication channels***[2] for citizens to interact with the city and having cities that ***engage in more meaningful communication with their citizens***. The need for clear communication channels between the city and its citizens comes from the need for the city to ***understand citizens*** and ***reflects the citizens' needs in technological design.*** As some interviewees pointed out: whom is the city built for, if not for its citizens, and if the city does not understand its citizens and what they want, then there is a major problem. Interviewees voiced the need for new forms of engagement and new platforms to encourage the citizen to be discerning and enable them to make more objective and systematic decisions.

> *We need new forms of engagement, new platforms to encourage citizens to be discerning, meaning to be able to understand the different thought collectives out there, to be able to understand the different interests and influences that are at play, and for them to be able to make more objective and systematic decisions on how we should proceed based on these different interests and influences. – I6*

Another issue voiced by multiple interviewees was that citizens often lack channels to communicate with the city. Having one ***clear communication channel,*** marketed by the city**,** with ***subcategories for issues and suggestions,*** would be a huge improvement for citizen participation in smart cities.

> *I believe that the smart city should have an official channel, with discussions threads on different city sectors. Right now we have Facebook groups, but they are unofficial and there are different degrees of activity between them. – I5*

Such a communication channel allows citizens and the city to ***co-create their vision*** of what the smart city should be. Additionally, granting citizens a ***sense of ownership*** over urban planning initiatives is a key

[1] https://naturvation.eu/

[2] The ***Italic boldface*** parts of the text represent open codes generated during data analysis

component of citizen engagement, creating a positive engagement cycle.

Finally, engaging citizens in the early stages of planning and embedding tools for participatory engagement into municipal planning structures is another key insight into improving collaboration between citizens and the city. This is reflected in the following excerpt: *Citizen engagement needs to happen at a very early stage and on every level. – I1*

According to the interviewees, citizen engagement often happens too late in the process of planning and development to have any meaningful impact apart from minor details and cosmetic nuances.

Some emphasis should be placed on passive participation, which can be done by revealing data to the city on how the citizen moves and interacts with the city, as many citizens do not actively wish to participate. To that end, open data services could play a key role.

## 4.2. Open data services

Our results show that open data services could improve citizen engagement and boost cities' climate resilience. Several interviewees mentioned that open data provides different avenues for citizens to produce and use data to co-create services or to contribute to improving existing services and apps. An example of this in the climate resilience realm is the screens showing air quality in the Helsinki metro system. It is important to note that open data in itself does not constitute positive change but rather how it is used to co-create smart city services with societal benefits. The following quote points out to this:

> *I believe that smart cities are the product of co-creation. It becomes a collective effort when data is open and accessible and can be used to create services and apps for the public good. – I5*

Ideally, open data would be used to influence positive changes in behavior by providing citizens with relevant information. One interviewee mentioned using open data to gauge individuals' carbon footprint relative to their consumption, which could influence more sustainable consumer behavior. One key insight from the interviews was the need for open data to be for the ***public interest instead of corporate interest.*** Therefore, the most important aspect of new open data solutions should be the ability to effectively ***demonstrate the benefits to the public*** in ways that are relevant to their everyday lives.

> *Open data can be used to create improved visualizations of climate change in ways that are more relevant to the average citizen, enabling and nudging the right kind of change that is needed. – I4*

To effectively collect and use open data, ***privacy and security*** must be addressed, which may lead to increased ***citizen trust***. When there is trust in the institutions and actors using the data, and the results are visible, it encourages citizens to share more data. ***Increased transparency*** in government processes is key to laying down the groundwork for increased trust in the government, fact-checking and influencing the government in ways that benefit the individual and the collective. To that end, ***citizen access to information*** is an essential consideration. Just as open data provides the city with increased amounts of information on citizens' daily lives, how they move, and their consumption habits, open data is a tool for citizens to gain more visibility into the processes of the city, its institutions, and the companies operating within it. This is reflected in the following quote from Interview 1: *Open data should increase the transparency of governance and enable fact-checking in the public sector.*

A key challenge surrounding open data is the sheer volume of data and the tendency for it to be fragmented. To combat this, evidence shows that there should be ***one clear database or dashboard*** to access all of this data. Ideally, everyone would know where to find it, has access to it, and knows how to use it while data is being kept completely anonymized. This would require background processes to maintain and categorize the different types of data into clear subsections but could greatly benefit both the public and the government in terms of ***easier access to relevant data***.

## 4.3. Smart sustainable cities

Our analysis shows that improving sustainability in smart cities requires ***holistic thinking***, ***ambitious climate targets***, ***considering long-term scenarios***, and ***adaptable urban development***. Green buildings, such as wood construction, could greatly mitigate the emissions of the construction sector. However, this is only the first step, and sustainable wood construction also requires the sustainable management of forests. Coupling green buildings and ***green infrastructures*** with a societal understanding of the carbon footprint and causality would make society more adaptable to climate changes. Long-term scenarios, such as the sea-level rise and increased rainfall, should be considered when planning the construction of new buildings and urban areas. For example, in the *Kalasatama* neighborhood in Helsinki, newer buildings are

constructed with sea-level rise in mind, with the first floors being constructed at an elevation that takes that into account. This is reflected in the following excerpt:

> *Ambitious targets, longevity, and taking into account long-term scenarios are important. For example, carbon neutrality goals are often given up on due to the belief that they are not possible to achieve at this moment in time - I1*

Green buildings and green infrastructures can be combined with and augmented by ***nature-based solutions***, which take natural processes and uses them in resolving societal issues. These solutions can be anything from green walls to green roofs and stormwater swales. A good example of this is using stormwater management to irrigate green areas and unburden water management facilities, using new forms of wetlands or water squares, for instance. A key focal point of nature-based solutions is creating space in the urban environment for natural processes, thereby bringing nature closer to the public. Many of these solutions surrounding adaptable urban development require ***sensors***. Sensors help us understand the current state and changes in our environment, be they changes in air quality, rainfall, sea-level rise, etc., and help us act or prepare accordingly. There are a number of climate resilience apps that operate using sensors. For example, one interviewee mentioned an app that monitors a given household's energy usage and optimizes energy consumption in heating and lighting according to the usage of space. Other examples include smart wastewater management initiatives and air quality sensors to improve weather forecasting and reduce vulnerability to heatwaves (Fernández & Peek, 2020).

Along with tangible climate resilience factors, intangible factors are equally important. This intangible side has to do with ***societal adaptability***, ***holistic thinking***, ***individual and group behavior***, and ***understanding the different interests and influences*** at play in the smart city. Taking into account ***couplings and feedback*** is an element of holistic thinking, which means looking into couplings instead of looking at these components on their own.

> *Climate resilience to me is about how we bring together the ecological design and nature-based solutions in ways to address the complex feedbacks between these different systems, and that does not occur by purely looking at technology alone or society alone. They have to come together into a multidisciplinary and arguably transdisciplinary understanding of the system. – I6*

It is of paramount importance for the average citizen to be aware of the ***politics, interests, and influences*** that are at play concerning urban development and climate decisions made by cities. This awareness allows citizens to be more discerning in their behavior and fosters the right kind of change. ***Activism*** is heavily associated with understanding ***politics, interests, and influence*** and gives citizens a way to add their own voice to the discussion and influence agendas and decision-making. Furthermore, ***thought collectives*** play a huge role in these discussions. Thought collectives are groups of individuals united by certain ideas. For example, citizens vying for less car traffic and more cycling constitute a thought collective. According to an interviewee, citizens usually hover in between thought collectives, having many different ideals. Involving these thought collectives in public discussion, studying compatibilities and emerging conflicts, while not necessarily solving those conflicts but celebrating divergencies could be an important way forward to climate resilience. We have to be able to ***demonstrate the benefits*** of the transformations needed for the community.

> *We have to be able to demonstrate the benefits of that to the community. It needs to be science-informed, but we also have to have the governance and political processes to bring different thought collectives into the picture so that, when we navigate these conflicts that are emerging, and not necessarily always solve them but have them more transparently discussed, and being part of the agenda. – I6*

Finally, to combine the tangible and intangible solutions of climate resilience, active urban experimentations or regional experimentations should be developed that not only engages diverse actors but also can bring in issues of power, influence, and interest in ways that are currently missing, that enable reflexivity and people from different perspectives to really think through the issues in ways that may not always be comfortable. That calls for linking the technologies around science and the methods of participation to the engagement processes. In effect, combining citizen engagement with open data to build climate resilience.

## 5. Discussion

In this section, we discuss our findings and highlight the contributions to smart city research and practice.

### 5.2. Theoretical contributions

This study builds on previous IS research on smart cities and open data, as well as the literature on climate resilience and citizen engagement. As such, we contribute to IS literature, especially the smart city research, by filling the gap that exists at the intersection of climate resilience and smart city research.

We provide a glimpse of the possibilities of tapping into the potential of using open data services for improving citizen engagement in urban climate resilience initiatives. Previous research suggests that when viewed as a collaborative innovation platform, the smart city can foster solutions that tackle key societal and urban challenges (Walravens et al., 2014). However, we lack structures or processes for integrating climate resilience in smart cities and urban development (Wamsler et al., 2020). Additionally, the lack of citizen engagement and failure to systematically capture their expectations could hinder sustainability in smart cities (Wamsler et al., 2020). Our findings indicate that open data tools and services could be the key to addressing these shortcomings and improving the structural conditions for citizen engagement to boost climate resilience.

In line with previous research (e.g., Moraci et al., 2018), our results show that improving citizens' awareness of climate issues and communicating the benefits of climate initiatives for them is important to improve citizen participation and engagement in building climate resilience. Additionally, to effectively collect and use open data, privacy and security must be addressed (Fernández & Peek, 2020; Hossain et al., 2016). This can lead to increased citizen trust, whereby the process becomes an aforementioned positive cycle, feeding itself (Meijer et al., 2014). The potential is there, but it is currently untapped (Wamsler et al., 2020).

### 5.1. Practical implications

Our results help smart city practitioners to tap into the potential of citizen engagement and participation in building climate resilience. To that end, we list several recommendations for improving citizen engagement and climate resilience in smart cities.

First, all the interviewees advocated for official communication channels between the city and its citizens. Through these channels, the city could understand the needs of individuals and groups. This is essential for building resilience, as citizens could potentially identify climate vulnerabilities and targets for improving their respective local areas.

Second, due to the enormous volume of existing and emerging data, well-structured open data platforms and dashboards should be implemented to store and categorize data depending on its nature. This makes open data easily accessible by citizens, corporations, and public entities alike for developing different smart city applications and services to improve climate resilience.

Third, the smart city must ensure the privacy, anonymity, and security of citizens' data and give them a choice in what data they want and do not want to share. This needs to be guaranteed in order to obtain citizen trust, which is the key to successful engagement and participation in urban development initiatives. Without trust, there can be no cooperation.

Fourth, active urban and regional experimentations need to be developed that not only engage diverse smart city actors but bring in issues of power, interest, and influence to enable discerning and reflexive discussions among citizens with various perspectives. No matter what the solution or experimentation may be, it needs to be evidence-informed, and we need to be able to demonstrate its benefits to the public.

Fifth, crowdsourcing, collaborative platforms, and workshops such as participatory mapping and budgeting are effective ways to engage citizens in building climate resilience in cities. Multiple people with diverse perspectives and backgrounds often come up with better and more solutions than a few experts working in-house. However, it is important to pass the “ownership” of the proposed solutions to the citizens and financially incentivize sustainable and climate resilience solutions. It is also critical to engage citizens at a very early stage to both attain a meaningful level of input, as well as for citizens to gain a sense of purpose and therefore encourage continuous participation.

### 5.3. Limitations and future work

Our results are based on seven semi-structured interviews. Although the interview subjects were a diverse array of professionals from different sectors and of differing backgrounds, the number of interview subjects can also be seen as a limitation of the study. Our results may have been influenced by the limited geographical scope of the research settings and certain

socio-economic conditions. Therefore, further research in diverse settings is needed to provide an in-depth understanding of the research phenomenon. Future empirical studies can investigate the effects of official digital communication channels between governing institutions and citizens on climate resilience building. Furthermore, studying the difference between current adaptive urban planning and experimentation co-creation in adaptive urban planning under favorable policy changes could shed light on the true potential of climate resilience building through citizen engagement.

## 6. Conclusions

Smart cities were born out of the need to adapt to and overcome the challenge of urbanization and climate change. However, until now, they have mostly focused on using advanced technologies to make cities more functional while paying less attention to the social and environmental aspects of urban development. We suggest that greater emphasis must be placed on the environmental and social dimensions of sustainability in the smart city debate, encouraging different actors, including citizens, to engage in building climate resilience in smart cities. To that end, open data and citizen engagement, both of which build trust in city governance, are crucial for strengthening the connection between citizens and the city. We posit that data platforms and dashboards providing secure access to well-structured urban data can be used for developing climate initiatives and solutions and demonstrating their benefits to the public. Additionally, clear and official communication channels between the city and its citizens enable cities to gain an understanding of citizens' needs and expectations. Finally, participatory initiatives alongside active urban experimentation are effective ways to engage a diverse group of actors in building climate resilience in smart cities. Future empirical research across contexts is needed to gain an in-depth understanding of how open data services and citizen engagement can support smart cities in tackling the climate crisis.

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## Appendix A. Interview questions

*1. What does the term smart city mean to you? What aspects come to your mind?*

*2. What do you think are the most important aspects of a successful smart city?*

*3. What does climate resilience look like to you? What comes to mind?*

*4. What do you think are the most important aspects of building climate resilience?*

*5. What do you think are the biggest challenges concerning citizen participation? How would you address these challenges?*

*6. Are you familiar with the term "open data"? What does that look like to you?*

*7. How important do you think open data is in regards to smart city governance? Can you give me some examples of successful uses of open data?*

*8. What do you think would be the most effective ways of engaging citizens in decision making concerning smart cities?*

*9. How do you think climate resilience and sustainability can be improved in cities?*

*10. How do you see citizens' role in building more climate resilient cities?*