Smart Communities in Climate Disasters: A Case of Porto Alegre, Brazil

Carolina Tavares Lopes [a*], *Edimara* Luciano [a*], *Lucas* Roldan [a*].

[a] Graduate Program in Business Administration (PPGAd), PUCRS Business School, Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, Brazil, email address [carolina.lopes004@edu.pucrs.br], ORCID number [0009-0004-4654-8503].

Abstract. This study explores the role of smart communities in responding to climate disasters, focusing on the 2024 floods in Porto Alegre, Brazil, as a case study. Grounded in existing concepts of smart communities and based on 23 in-depth semi-structured interviews with community leaders, community members, community collaborators, and local government authorities, this research employs an existing framework designed to understand how these communities evolved into smart communities and whether their adoption of smart governance practices helped them mitigate the disaster's impacts and navigate the recovery process more effectively. The findings, derived from a qualitative data analysis, reveal that pre-existing smart communities demonstrated greater effectiveness in coordinating disaster response efforts, mobilizing resources, and building resilience. Community cohesion was reinforced during the crisis, largely due to established networks, collective trust, and decentralized governance mechanisms. However, the study also identifies significant challenges, particularly concerning the availability and reliability of ICT-based communication systems during crises, difficulties in coordinating across different levels of government, and broader governance barriers that are especially pronounced in developing countries like Brazil. By highlighting these dynamics, this study offers valuable insights into how smart communities can be strengthened to enhance disaster response and resilience, particularly in urban areas facing increasing climate risks. More than just showcasing best practices, this study emphasizes the importance of human connections, local knowledge, and governance innovations, demonstrating that integrating community-led governance into formal disaster planning is essential for proactive and adaptive urban resilience.

Keywords. Smart Community, Climate Disaster, community-led governance, urban resilience, disaster governance.

1. Introduction

Over half of the world's population lives in urban areas, a figure expected to reach 75% by 2050 (McKinsey, 2011). This rapid urbanization, combined with climate change, heightens vulnerability to climate-related hazards, such as urban flooding and extreme weather events (United Nations, 2019). Densely populated cities, particularly in Latin America, are highly susceptible to extreme weather events such as heavy rainfall and urban flooding, exacerbated by the urban heat island effect (Shastri et al., 2015; Li et al., 2020).

This reality is evident in Latin America, where 80% of the population already resides in cities, a figure expected to reach 85% by 2040 (UN-Habitat, 2022). Nearly half of Latin America's capital cities are at extreme risk due to climate change (CAF, 2014), emphasizing the need for resilience strategies in urban governance.

The growing frequency and severity of climate disasters further highlights the urgency of urban resilience strategies. According to the World Meteorological Organization (WMO), between 2020 and 2022, 88% of extreme events recorded in Latin America were caused by meteorological, climatic, and hydrological factors, accounting for 40% of disaster-related deaths and 71% of economic losses (WMO, 2022). As the frequency and intensity of these

disasters escalate, it becomes evident that enhancing urban resilience is not just necessary but urgent. Among these hazards, flooding stands out as one of the most recurrent and destructive, driven by climate change projections and rapid urban expansion (Rozer et al., 2021). The economic and social costs of flood-related damages continue to rise, disproportionately affecting low-income and socially vulnerable urban communities (Nkwunonwo et al., 2020; Nasiri et al., 2016).

As Latin American cities grapple with increasing climate risks, Porto Alegre, Brazil, stands out as a compelling case study, particularly due to its long-standing tradition of participatory governance and community engagement. The devastating 2024 floods, which affected large parts of the city, faced the urgency of understanding how urban communities can build resilience in climate disasters (World Meteorological Organization [WMO], 2024). On top of that, this event triggered urgent discussions on disaster governance and flood resilience.

Porto Alegre's pioneering participatory governance, notably through the Participatory Budgeting (PB) process, provides a unique lens to examine how smart communities can enhance resilience in disaster scenarios (Baiocchi, 2003; Goldfrank, 2011). This long-standing tradition of community participation in municipal decision-making offers a valuable lens through which to examine the role of smart communities in disaster response. Additionally, the city has been actively involved in smart community initiatives and innovative governance practices, making it a compelling case for understanding how local governance contributes to disaster resilience (Pereira et al., 2017).

While *smart cities* have been extensively explored (Harrison & Donnelly, 2011; Komninos, 2013; Caragliu et al., 2011), research on *smart communities*, particularly in the context of disaster resilience, remains limited. Much of the existing research emphasizes technological solutions (Janssen, Charalabidis, & Zuiderwijk, 2012) and infrastructure-driven adaptation strategies (Alawadhi et al., 2017), while the role of community-led governance in climate disasters remains understudied (Craig et al., 2004). There is limited research on how smart communities develop in crisis contexts, particularly in urban areas of developing countries, where challenges such as institutional fragmentation, lack of coordinated response mechanisms, and social vulnerabilities pose additional complexities (Reardon & Forester, 2015).

This study examines how Porto Alegre's *smart communities* adapted to the 2024 floods, offering insights into how localized governance and community-driven initiatives can enhance resilience in the face of climate disasters. More specifically, it investigates whether their adoption of smart governance practices played a role in mitigating the disaster's impacts and how facilitating an effective recovery.

To guide this discussion, the paper is organized as follows: Section 2 reviews the concept of smart communities and introduces the conceptual framework used to analyze their structure. This is followed by an overview of Porto Alegre's geographic and historical context, with a focus on the 2024 floods. Section 3 details the research methodology, outlining the data collection process, which combined in-depth interviews with document analysis of secondary data sources. Section 4 presents the key findings, exploring how communities engaged with the disaster response and recovery efforts. The discussion that follows cross-analyzes these results, offering insights into the mechanisms of community governance and the role of smart communities in fostering resilience. Finally, the conclusion highlights the importance of strengthening smart local communities and ensuring their integration into decision-making processes as a strategy to enhance climate disaster resilience.

2. Theoretical Background

This section introduces the concept of smart communities and their role in urban resilience, followed by a conceptual framework to analyze how these communities' function in Porto Alegre, particularly during the 2024 floods. Finally, we provide an overview of the city's geographic and historical background, highlighting the factors that influence its governance and disaster response strategies.

2.1 Smart community and Climate Disasters

Smart communities, an extension of smart cities, focus on collaborative governance, technological integration, and social resilience, especially in the face of urban challenges like climate disasters. Unlike traditional top-down governance models, smart communities prioritize citizen engagement, participatory decision-making, and decentralized problem-solving (Komninos, 2013; Craig et al., 2004). Smart communities leverage technology and local resources to enhance governance and community well-being, playing a critical role in building urban resilience during climate disasters (Ahvenniemi et al., 2017). They also function as microcosms of larger urban ecosystems, subdividing cities into smaller, interconnected networks that facilitate more efficient governance and localized problem-solving (Tang, 2022).

Instead of depending exclusively on top-down government policies, smart communities promote a participatory approach that enhances local governance, improving urban planning, and social cohesion (Bartoletti & Faccioli, 2016). In this sense, smart communities operate through intersectoral collaboration, promoting active citizen

participation in decision-making, public service monitoring, and direct engagement with government agencies (Alawadhi et al., 2017).

O'Toole et al. (2010) reinforce that community governance flourishes when residents feel a sense of ownership and collective responsibility, making them key actors in shaping local policies and ensuring that resources are allocated effectively. In this context, smart communities thrive when supported by strategic collaborations with local governments and other entities, ensuring that services align with the specific demands of the population. These partnerships enhance the adaptability of governance models, making policies more responsive to evolving social and environmental challenges. Differ than functioning independently, smart communities work alongside existing governance structures, using citizen participation and technology to enhance decision-making (Bowles & Gintis, 2002). Instead of replacing governments or markets, they act as interconnected actors that reinforce governance through collaboration. O'Toole & Burdess (2004) expand on this argument, showing that when local governance structures actively encourage community participation, residents and organizations take on a more proactive role in shaping and delivering public services.

Smart communities rely on social capital, fostering trust between citizens and institutions, which is essential for effective governance during crises (Hautekeur, 2005). However, the sustainability of these governance models is not always guaranteed. While self-organized communities enhance urban resilience, particularly through organic adaptation strategies, their long-term success depends on alignment with formal governance structures (Marasco et al., 2022). Nam & Pardo (2011) point out that maintaining adaptability is a growing challenge, as communities must continuously evolve with technological advancements, ensuring that residents can fully engage with and benefit from smart governance structures.

Yet, the reality is that many community-driven initiatives struggle to sustain long-term engagement. Farmer et al. (2015) argue that despite initial enthusiasm, many of these efforts face significant challenges in translating participation into lasting structural changes. One of the key barriers is the lack of integration with formal governance structures, which can result in community-led solutions being overlooked or failing to gain institutional support. Without clear mechanisms for long-term implementation, mobilizing local actors can lead to frustration and disengagement. Berardi (2013) and Alawadhi et al. (2012) echo this concern, showing that while smart communities represent an evolution of social governance, their effectiveness depends on a continuous process of innovation, adaptation, and institutional backing.

Despite these challenges, smart communities play a key role in urban governance, especially in disaster scenarios like the 2024 floods in Porto Alegre, where institutional inefficiencies hinder rapid response (Phong & Shaw, 2009). In developing countries like Brazil, issues such as fragmented governance, limited digital infrastructure, and a lack of coordinated response mechanisms often exacerbate the impacts of climate disasters (Mutiarni et al., 2022). Community-led adaptation strategies, such as those seen in Indonesia — a country frequently impacted by climate disasters — have been shown to improve disaster mitigation and post-crisis recovery by formally recognizing and supporting local climate action efforts (Azizi et al., 2022). Moreover, Parvin et al. (2023) emphasize that addressing climate risks effectively requires expanding collaboration beyond government agencies, incorporating a diverse network of stakeholders, including local communities, private organizations, and international institutions.

A key element of disaster-resilient smart communities is the integration of ICT-based communication systems, which allows for real-time information sharing and enhanced coordination between citizens and public authorities (Pereira et al., 2017). Communities with well-established governance structures and active digital platforms are often more effective at mitigating disaster risks and accelerating recovery efforts (Janssen, Charalabidis, & Zuiderwijk, 2012). However, technology alone is not enough — without strong social cohesion and well-structured governance models, digital solutions may fail to achieve their full potential in crisis situations. Reardon & Forester (2015) illustrate this risk through the example of post-Katrina New Orleans, where institutional efforts to increase urban resilience ultimately resulted in the exclusion of vulnerable communities from the recovery process, reinforcing socioeconomic disparities rather than reducing them. This case presents the importance of ensuring that smart governance frameworks prioritize inclusivity, preventing marginalized groups from being left out of resilience-building efforts.

The intersection between smart governance and climate resilience highlights the need for cross-sector collaboration, particularly in urban contexts where government agencies, NGOs, local businesses, and community representatives must work together to strengthen disaster preparedness (Reardon & Forester, 2015). Tedong & Zyed (2021) further emphasize that communities serve as the foundation of sustainable urban development, reinforcing the idea that resilient communities are essential to the long-term success of smart city initiatives. The case of Porto Alegre provides an opportunity to explore how smart communities emerge in times of crisis, offering insights into both their strengths and the challenges they face when integrating community-led initiatives with formal governance frameworks.

2.2 Conceptual Framework for Smart Communities in Porto Alegre

Building on existing theoretical perspectives, this study applies a previously developed conceptual framework to analyze how communities in Porto Alegre develop and function as smart communities. This framework offers a relevant foundation for understanding the governance mechanisms and institutional responses that shape their evolution. Illustrated in Figure 1, the model is grounded in insights from 25 in-depth interviews conducted with community leaders, community social center personnel, citizens, entrepreneurs and consultants, and city hall representatives. Its primary objective is to map the interactions between community-driven governance mechanisms and institutional response strategies, providing a structured perspective on how these communities emerge, evolve, and establish smart governance practices.
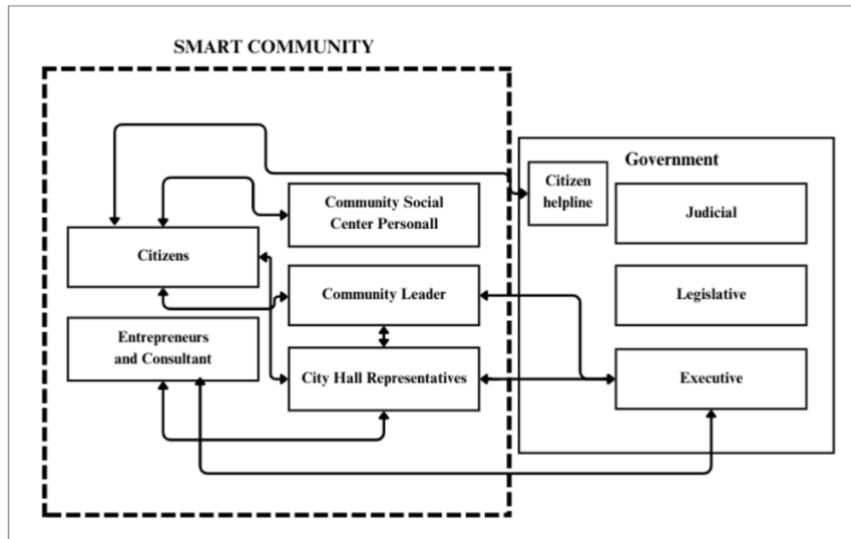

Fig. 1 - Figure caption. Smart Community Framework (Lopes et. al.,2024)

This framework presents how communities address local challenges, filling communication gaps and compensating for inefficiencies in government action. These communities are not formed arbitrarily; rather, they emerge as individuals come together, building networks to draw attention to pressing issues, advocate for public services, and, in some cases, bypass bureaucratic barriers to implement solutions themselves.

The framework reveals the diverse roles that smart communities play — not just as spaces for collaboration, resource sharing, and civic engagement, but also as meeting points that foster local innovation. Participants express a shared need for governance structures that are more inclusive and responsive, where citizen input is not only acknowledged but actively incorporated into decision-making processes. Over time, these communities establish credibility, making it harder for institutions to overlook their demands.

The proposed framework seeks to understand how communities become smart, shedding light on the mechanisms that allow a group of individuals to self-organize, communicate, and advocate for solutions that address local challenges. Ideally, once a community identifies its needs, leaders engage directly with local representatives, such as city councilors, to push for improvements, facilitating dialogue and resource allocation. However, if direct engagement with government structures remains ineffective over time, communities seek alternative channels — whether through city council representatives, local media, or the legislative chamber — to escalate their concerns. In certain cases, organized demonstrations, advocacy campaigns, or legal actions are necessary to ensure that institutional actors acknowledge and respond to their demands.

This model, grounded in the data collected, portrays a pragmatic vision of smart communities—one that is not solely focused on long-term structural change but also on the capacity to address recurring challenges through collective action and strategic partnerships. In the Section 4, we explore how this structure operates in the context of climate disasters, examining the role of smart communities in mitigating risks and enhancing local resilience.

2.3 Porto Alegre's geographic and historical context

Porto Alegre, the capital of Rio Grande do Sul, is Brazil's southernmost state, bordering Uruguay and Argentina. Founded in 1772 as a strategic port city, it quickly became an economic and political hub, shaped by waves of European immigration that played a central role in the city's urban development and social fabric (Constantino, 1998). German, Italian, Portuguese, and other immigrant communities settled in distinct neighborhoods,

establishing businesses, industries, and civic institutions that contributed to the city's economic growth and cultural identity. Over the decades, Porto Alegre has distinguished itself as a leader in participatory governance, particularly through its internationally recognized Participatory Budgeting (PB) initiative, which has influenced urban management models worldwide (Baiocchi, 2003; Goldfrank, 2011).

Geographically, Porto Alegre is located along the Guaíba River, a defining feature that has historically shaped its economy, infrastructure, and urban expansion. However, this proximity to a vast hydrographic system also makes the city highly susceptible to flooding, a vulnerability that has been exacerbated by rapid urbanization, insufficient drainage infrastructure, and climate change effects (Rozer, Vogel, & Costa, 2021). The topography of the city, characterized by low-lying areas interspersed with hills, further complicates flood management, with several neighborhoods frequently experiencing inundation during extreme weather events (Silveira, 2023).

Historically, Porto Alegre has faced severe flooding events, with two particularly significant disasters shaping urban resilience strategies. The 1941 flood was one of the most catastrophic in the city's history, when extreme rainfall caused the Guaíba River to rise to an unprecedented 4.75 meters, submerging large parts of the city, including its downtown area. Nearly 70,000 people — approximately 26% of the city's population at the time — were displaced, and a third of the city's businesses and industries wereaffected (Silveira, 2023). The flood lasted approximately 40 days, marking it as one of the most extreme climate events recorded in southern Brazil. In response, authorities implemented structural flood control measures, culminating in the Porto Alegre Flood Protection System, completed in 1974, which includes a network of levees, pumping stations, and the controversial Mauá Wall, built along the waterfront to prevent future disasters (Guimaraens, 2009).

Despite these structural interventions, Porto Alegre continues to face significant flood risks. As highlighted by Valenti, Rolim & Rocha (2012), the city is particularly vulnerable due to its low altitude, with an average elevation of 4 meters above sea level, making floodwaters harder to control. The hydrographic system of Porto Alegre is complex, with the Guaíba River receiving water from four major tributaries — the Jacuí, Sinos, Caí, and Gravataí Rivers — which significantly increases runoff volume during heavy rainfall events. Moreover, the impermeabilization of urban surfaces due to rapid expansion has further reduced natural drainage, exacerbating flood impacts.

The 2024 floods, one of the most devastating climate disasters in the city's recent history, reinforced these concerns (WMO, 2024). As seen in previous flood events, community-led initiatives played a critical role in response and recovery, stepping in where governmental structures faced delays or inefficiencies. The disaster renewed urgent discussions on urban resilience and disaster governance, emphasizing that while Porto Alegre has a history of participatory governance, its institutional framework and infrastructure must continue evolving to address increasing climate risks.

Given Porto Alegre's historical legacy of civic participation and its ongoing exposure to climate risks, it serves as an important case to analyze the role of smart communities in disaster resilience. Understanding how grassroots networks interact with formal governance structures allows for a broader discussion on disaster preparedness, crisis management, and long-term climate adaptation strategies.

3. Research Method

This section outlines the methodological approach used in the study, applying qualitative research frameworks to explore governance within smart communities. The methodology follows Arksey and O'Malley (2005) and Godin et al. (2015), integrating literature reviews, semi-structured interviews, and grey literature analysis to explore how smart communities respond to climate disasters. The research examines smart community responses to the 2024 floods in Porto Alegre, structured into five phases: 1) Analysis of a previously developed conceptual framework on how communities become smart. 2) A systematic literature review to establish a theoretical foundation on smart communities and climate resilience. 3) First-hand observation of the 2024 floods and how smart communities mobilized during the crisis. 4) Reanalysis of semi-structured interviews with diverse stakeholders conducted before the disaster, and 5) a scoping review of grey literature and secondary data sources to further understand institutional responses and governance gaps. Each phase contributed to a deeper understanding of how community-driven governance mechanisms operate before, during, and after climate disasters. The combination of multiple qualitative research methods allowed for a comprehensive analysis, ensuring methodological rigor while capturing the complexity of smart community dynamics in crisis contexts.

3.1 Research design

This study employs a qualitative approach to examine governance dynamics within smart communities in Porto Alegre. Since this study aims to understand how communities mobilize, organize, and interact with governance structures, qualitative methods offer the depth needed for an in-depth exploration (Pozzebon, 2004). However, considering the use of secondary data and the scoping review of grey literature, the study also integrates elements

of a mixed-methods approach, allowing for a broader analysis that includes policy reports and institutional documents.

The study builds upon a pre-existing conceptual framework, presented in 2.2, (Lopes et al., 2024) that explores how communities adopt governance practices and use technology to engage with public authorities and other stakeholders. This framework serves as a reference for analyzing the governance structures of smart communities in Porto Alegre.

Following this, a systematic literature review was conducted to strengthen the theoretical foundation on smart communities and climate disasters. The review followed Ridley's (2012) methodology, involving the selection and organization of relevant studies, the interpretation of key texts, and the synthesis of findings in alignment with the research objectives. The search focused on the terms "smart community" and "climate disasters" in the Scopus database, yielding 24 relevant academic sources, which were analyzed and integrated into the study.

3.2 Data collection

To better understand governance mechanisms in smart communities, we conducted semi-structured interviews, which provided flexibility for open-ended responses while ensuring comparability across participants (Benz & Eberlein, 1999). Given the complexity of governance structures, we adopted a multi-level approach to capture diverse stakeholder perspectives.

We conducted 25 interviews in Porto Alegre over two months in 2023, focusing on governance in climate-related contexts. A total of 23 interviews were selected for analysis. Participants were chosen based on their involvement in Community governance and their ability to provide insights into how smart communities function during crises. The selected interviews included representatives from four primary groups: a) Community leaders who organize and advocate for local initiatives, b) community collaborators who work within these communities, often sharing the same values and goals, c) community members who actively participate in governance and neighborhood associations, and d) local government representatives responsible for urban policies and disaster response efforts.

Interview sessions lasted between 40 and 100 minutes and were recorded with participant consent. The discussions focused on how smart communities interact with public authorities, coordinate internally, and organize around collective challenges. The interviews also provided a means of triangulating insights gathered from literature reviews and document analysis, reinforcing the study's findings.

Following the floods of May 2024, the lead author conducted additional fieldwork, initially as a volunteer supporting affected communities. This direct engagement provided an opportunity to observe smart community dynamics in real-time. Unlike the previous phase, no new interviews were conducted due to the sensitivity of the situation. Instead, observations focused on identifying how previously studied governance structures adapted in response to the crisis. Given the scale of the disaster, extensive secondary data was also available from reports produced by community organizations, local governments, and research institutions.

To complement primary data, a scoping review of grey literature was undertaken, drawing on reports from international and national institutions, including the World Bank, IBGE, and municipal research centers. Arksey and O'Malley (2005) note that scoping reviews are particularly useful in emerging research areas where empirical studies may still be limited. Similarly, Godin et al. (2015) highlight the value of grey literature in bridging academic research with policy and practice. Our review included policy briefs, governmental documents, and community-led publications, offering broader institutional perspectives on urban resilience and governance.

3.3 Data analysis

Data was analyzed using qualitative content analysis to identify governance patterns and themes within smart communities. A deductive coding strategy was applied, drawing from theoretical insights and key themes identified in the literature (Pozzebon, 2004). All interview recordings were transcribed using the qualitative data software Transkriptor. The transcripts were then imported into NVivo for thematic analysis, enabling the identification of central themes and recurring concepts. The analysis followed three stages: 1) Coding of key governance interactions and smart community structures. 2) Clustering of themes into broader categories aligned with research questions. 3) Identifying patterns across stakeholder groups to detect trends in governance models. In parallel, the scoping review of grey literature was analyzed using document analysis techniques to extract relevant policy insights and governance responses. This allowed us to integrate multiple sources of evidence, further validating the study's findings.

The final phase of analysis involved revisiting the conceptual framework to incorporate insights from the case study. By examining how smart communities in Porto Alegre mobilized before, during, and after the 2024 floods, the study refined the existing framework, expanding it into a more comprehensive model—Smart Communities

2.0. This revised model accounts for the practical governance challenges faced by communities in crisis situations, emphasizing adaptive mechanisms and multi-stakeholder collaboration.

By combining literature review, semi-structured interviews, ethnographic fieldwork, and grey literature analysis, the study provides a nuanced examination of how smart communities navigate climate disasters. The integration of these methodological steps ensures that findings are grounded in both theoretical perspectives and empirical observations, offering valuable insights into the intersection of community resilience and urban governance.

4. Discussion

This discussion synthesizes insights from 23 in-depth interviews with community leaders, local residents, and government officials, along with documentary analysis, to explore how smart communities responded to the 2024 floods in Porto Alegre. It examines the challenges faced and the role of community governance in enhancing urban resilience.

4.1 The Porto Alegre 2024 Floods: A Case Study

The May 2024 floods reached unprecedented levels, with the Guaíba River peaking at 5.37 meters at Cais Mauá, surpassing the highest recorded flood in the city's history by 45 cm (Serviço Geológico do Brasil [SGB], 2024). The disaster had a devastating impact on urban infrastructure, exposing Porto Alegre's vulnerability to climate-related hazards. The city's main bus terminal remained closed for a month due to flooding (Prefeitura de Porto Alegre, 2024), while the Salgado Filho International Airport was shut down for over eight months, severely disrupting mobility, and logistics across the state (Governo do RS, 2024). Additionally, several stations of the Trensurb urban train system were submerged, interrupting railway connections between the capital and its metropolitan region for four months. By December 2024, three stations were still closed, further complicating daily commutes for thousands of residents (Governo do RS, 2024).

The social impact of the disaster was equally severe. More than 377 people remained displaced months after the event, while many families were relocated through the Compra Assistida program, which provided homes worth up to R$ 200,000 to those who lost their properties (United Nations, 2024). The destruction of residential areas was exacerbated by the failure of the Muro da Mauá, a flood protection structure built over fifty years ago. Its floodgates, designed to prevent water from entering the historic downtown area, failed to seal properly, allowing extensive inundation in one of Porto Alegre's oldest and busiest districts (Prefeitura de Porto Alegre, 2024).

Institutional analyses of the event indicate that the flooding was intensified by a combination of the El Niño phenomenon and the effects of climate change. El Niño, characterized by the abnormal warming of Pacific Ocean waters, disrupts weather patterns, and leads to increased rainfall in southern Brazil (World Meteorological Organization [WMO], 2024). This scenario underscores the urgent need to strengthen urban resilience by enhancing local governance mechanisms to mitigate the impact of extreme climate events in the future.

4.2 Communities Becoming Smart Communities in Climate Disasters

The literature on smart communities highlights their ability to self-organize, engage in civic participation, and collaborate with government institutions and private ones (Komninos, 2013; Hautekeur, 2005). During the 2024 floods, these three characteristics proved essential in disaster response.

Interviewee 1 emphasized that "when a community is organized, it gains political leverage to negotiate directly with the government — whether to veto projects or demand emergency actions" (Interview 1, 2023). Similarly, Interviewee 19 noted that, while community organization has weakened in recent years, leaders still manage to mobilize people more effectively than government agencies in times of crisis (Interview 19, 2023). This mobilization was instrumental in ensuring the swift implementation of the Compra Assistida housing program, which provided housing solutions for displaced families (United Nations, 2024). Beyond political advocacy, structured community networks were key to emergency response efforts. Interviewee 6 stressed that building partnerships with the government was crucial in securing resources and ensuring assistance reached the most vulnerable groups (Interview 6, 2023).

The findings align with the DRRS Porto Alegre Report (2024), showing that community-led networks were more agile than institutional responses, particularly in organizing donations, evacuations, and rescue operations. This highlights the critical role of community governance in urban resilience during climate disasters. Additionally, the Prefeitura de Porto Alegre (2024) recognized that many emergency shelters were initially organized by community groups rather than governmental institutions, demonstrating the power of grassroots mobilization. The effectiveness of these networks also reflects previous research indicating that well-organized grassroots communities play a crucial role in disaster governance, particularly when official response systems face delays (Krongthaeo et al., 2021). The Porto Alegre case reinforces that disaster governance must include community-led

initiatives as an integral component of urban resilience strategies (Marasco et al., 2022).

4.3 Community Credibility and Trust

The credibility of smart communities was crucial in mobilizing resources and fostering effective engagement with governance structures, enabling them to act swiftly and effectively during the crisis. According to Hautekeur (2005), community credibility—the trust communities hold—enables effective interaction with formal institutions. The trust in community-led mechanisms was evident during the 2024 floods, particularly through organizations like Fundação Cultural Floresta, which coordinated fundraising and distribution of essential goods. This highlights how strong community networks can complement and even enhance official disaster response efforts. Meanwhile, the Ação da Cidadania Sul, a local branch of the national Ação da Cidadania initiative, was instrumental in organizing emergency shelters and ensuring food security for displaced residents (Ação da Cidadania, 2024).

The long-standing credibility of these organizations played a critical role in their ability to attract donations and mobilize volunteers, reinforcing the argument that well-established community networks are essential for urban resilience (Marasco et al., 2022). This supports previous research indicating that communities with strong credibility can influence public policies and shape disaster response strategies (Craig et al., 2004).

Another key aspect was the role of community spaces as coordination hubs. Interviewee 9 described how community centers became "meeting points for organizing relief efforts and disseminating critical information" (Interview 9, 2023). This reflects research suggesting that community spaces act as focal points for collective action and mutual support during crises (Hautekeur, 2005). One striking example was the Velejadores Solidários RS, a sailing group that mobilized boats to rescue stranded families and later shifted to organizing donations of clean clothes, personal hygiene kits, and pet food for affected communities.

4.4 ICT and Smart Communities

The use of Information and Communication Technologies (ICTs) during the floods showed the potential of smart governance to improve climate resilience. For example, the interactive mapping platform by the municipal government helped track flood levels and coordinate emergency actions, demonstrating how ICT can enhance disaster response (Prefeitura de Porto Alegre, 2024b). Additionally, the ObservaPOA platform provided real-time data on the most affected neighborhoods, allowing communities to organize relief operations more effectively (Prefeitura de Porto Alegre, 2024a).

Digital governance research suggests that data-driven decision-making significantly improves crisis management (Lassa, 2019). Social media also played a critical role in facilitating decentralized coordination during the floods (Krongthaeo et al., 2021). However, technological solutions alone are insufficient—smart disaster governance must integrate local knowledge, citizen participation, and institutional support to be effective (Nam & Pardo, 2011). The Porto Alegre case illustrates that pre-established community hubs significantly enhance urban resilience, accelerating coordination and resource distribution.

4.5 Porto Alegre's Institutional Coordination and Smart Community Gaps

Despite the effectiveness of community-led networks, several governance challenges were identified. A major issue was the lack of coordination among different levels of government, which delayed response efforts. The DRRS Porto Alegre Report (2024) found that there were 3,500 open emergency protocols during the disaster, highlighting bureaucratic inefficiencies and response fragmentation.In a 2023 interview, a local government representative acknowledged these difficulties, stating that "there is no alignment between the objectives of secretaries, council members, and the mayor. Each has their own priorities, with no clear strategy" (Interview 18, 2023). This confirms findings by Takara (2018) and Meijer & Rodríguez (2016), which highlight administrative fragmentation as a barrier to adaptive governance.

The breakdown of official communication systems further complicated the response. According to the Prefeitura de Porto Alegre (2024), the collapse of ICT-based monitoring systems and early warning alerts left many residents without real-time updates, forcing them to rely on community networks for critical information.

Interviewee 17 recalled that during a smaller flood in September 2023, "Civil Defense came to talk to us, but did nothing. It was through the internet and community networks that we learned how to respond" (Interview 17, 2023). This sentiment was echoed in the DRRS Porto Alegre Report (2024), which noted that government agencies lacked real-time situational awareness due to system failures, increasing reliance on informal communication channels.

Another significant challenge was infrastructure failure, which exacerbated the flood's impact. The Muro da Mauá

flood barrier, built over 50 years ago, failed to prevent water from entering downtown Porto Alegre due to structural weaknesses in its floodgates (Prefeitura de Porto Alegre, 2024). The United Nations (2024) attributed part of the disaster's severity to the combination of El Niño and climate change, highlighting the urgent need for urban resilience planning.

The Porto Alegre case highlights the need for disaster response strategies that integrate multi-level governance, community engagement, and resilient digital infrastructure. Institutionalizing hybrid governance models that include smart community networks is crucial for improving crisis management in the future.

5. The Role of Smart Communities in Disaster Response

The 2024 floods in Porto Alegre presented significant challenges to urban governance and the city's response capacity. In this crisis, smart communities played a critical role in mobilizing resources, advocating for political action, and providing emergency support, effectively filling the gaps left by institutional responses. This experience reinforces the importance of community-driven governance models in strengthening resilience, fostering local coordination, and building trust networks (Hautekeur, 2005).

During the disaster, citizen-led initiatives proved essential in mitigating damages and organizing recovery efforts. Community-led mapping efforts utilized georeferenced tools to identify the hardest-hit areas, ensuring the efficient allocation of resources and prioritizing aid distribution. (Prefeitura de Porto Alegre, 2024a). Additionally, emergency relief coordination — largely driven by collaborative networks and social media — enabled faster distribution of food, medical supplies, and temporary shelter to displaced individuals (United Nations, 2024). In the aftermath of the floods, volunteers organized large-scale cleanup efforts, removing more than 13,000 tons of debris, demonstrating the power of collective action in disaster recovery (Prefeitura de Porto Alegre, 2024b).

The effectiveness of these community-driven responses not only helped alleviate the immediate crisis but also highlighted structural governance deficiencies that complicated disaster management. Local governments faced logistical and bureaucratic barriers, a common issue in Latin America, where institutional fragmentation hampers public sector efficiency (O'Toole & Burdess, 2004). The Porto Alegre case exemplifies this issue, revealing the urgent need to strengthen coordination between governments and communities to ensure a more agile and integrated response to future disasters. Based on the 2024 flood experience and insights from interviews, we identified three layers of community governance that played a pivotal role in disaster response:

Internal Community Dynamics – Autonomous grassroots networks that organize self-managed crisis responses, mobilizing resources and providing immediate support independently of government agencies.

Intermediary Actors – Social organizations, entrepreneurs, and non-profits that act as connectors, bridging the gap between communities, institutional resources, and the private sector to enable decentralized yet effective solutions.

Government Interaction and Institutional Support – Public policies and listening mechanisms that foster community engagement, reduce bureaucratic hurdles, and integrate grassroots efforts into official disaster response strategies.

These interconnected layers demonstrate the need for hybrid governance models, combining digital technologies, community engagement, and coordinated public policies, to build resilient urban environments capable of responding to climate crises (Reardon & Forester, 2015). Learning from the 2024 floods, we propose an updated Smart Communities Framework (Smart Communities 2.0) that integrates governance and technological innovations to enhance urban resilience (see Figure 2).
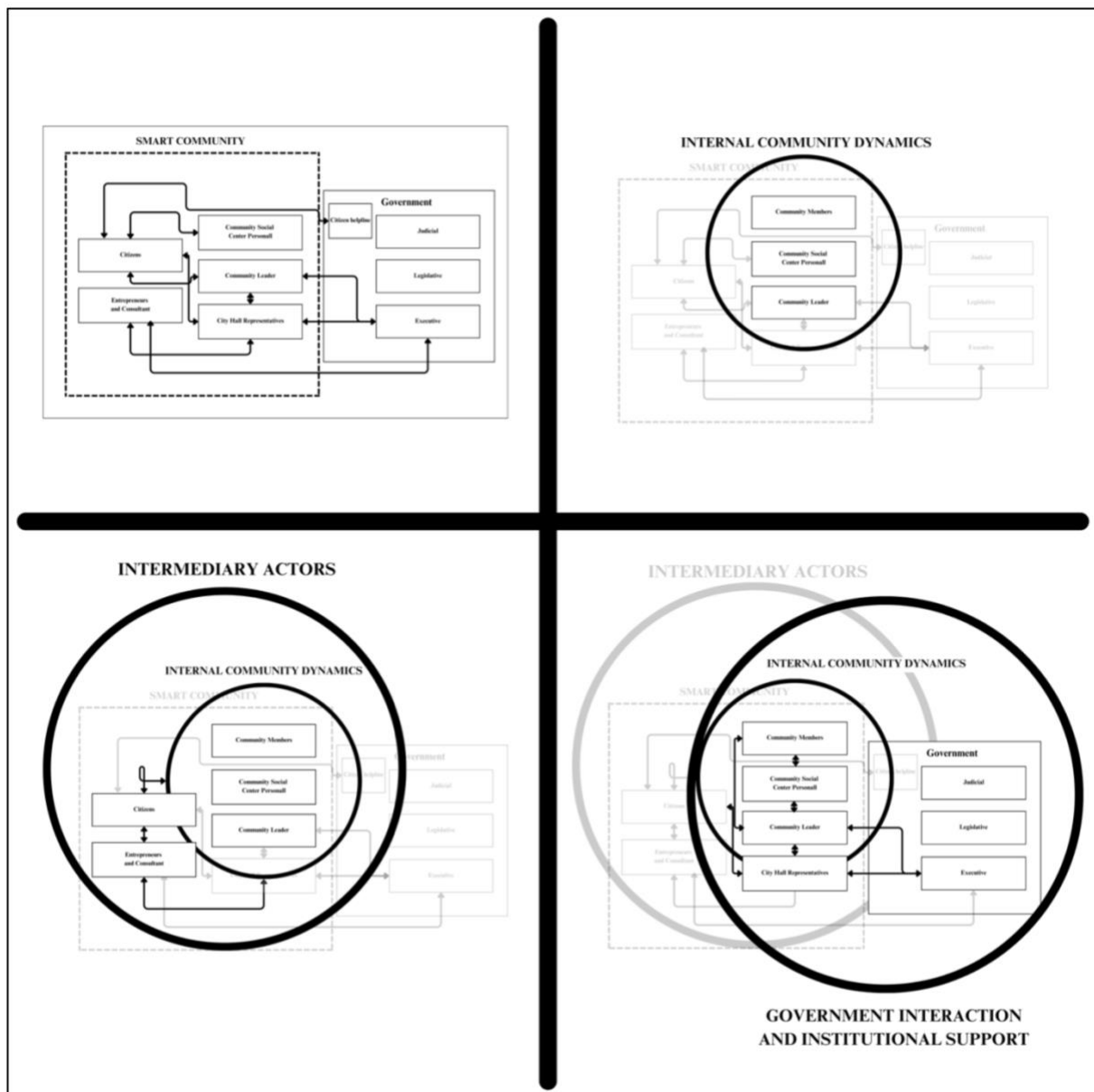
Fig. 2 - Smart Community Framework 2.0 (Created by the authors)

The evolution of Smart Communities as a concept is crucial for understanding their role in climate resilience. The Smart Communities 2.0 Framework aims to define how these networks function as key resilience-building actors, ensuring that climate-vulnerable cities are better equipped to withstand extreme events. This model is based on systematic literature review, qualitative interviews, fieldwork observations, and institutional reports, reinforcing the idea that decentralized governance structures are essential for disaster management.

Despite the proven effectiveness of community-led responses, there is still a significant gap in institutional policies recognizing and integrating smart communities as legitimate urban planning stakeholders. The Porto Alegre case illustrates this disconnect, while institutional responses were slow and fragmented, community-led initiatives were rapid, well-coordinated, and highly effective, forming support networks and accelerating recovery efforts. This finding highlights the importance of incorporating decentralized, participatory models into crisis governance, reducing the sole dependence on state agencies, and strengthening civil society's response capacity.

In the Latin American context, where challenges like inadequate infrastructure, social inequality, and political instability amplify the impacts of climate disasters, adopting the Smart Communities 2.0 Framework represents a transformative step forward. This model not only addresses immediate disaster response needs but also provides structural, long-term solutions, integrating technology, governance innovation, and community networks to create cities that are more resilient and prepared for future climate risks.

6. Final remarks

The 2024 floods in Porto Alegre underscored the crucial role of smart communities in resource mobilization, emergency response, and urban recovery. While institutional responses faced logistical and bureaucratic challenges, community networks proved to be more agile and effective, reinforcing the importance of decentralized governance in crisis scenarios. The collaboration between citizens, intermediary actors, and government agencies was crucial in mitigating the disaster's impacts and ensuring direct assistance to affected populations.

This study emphasizes the importance of the Smart Communities 2.0 Framework, illustrating how hybrid governance models can enhance urban resilience and better equip cities to respond to future climate disasters. Porto Alegre serves as a real-world case study that bridges theory and practice in the fields of adaptive governance and disaster management. Additionally, this research contributes to the broader discourse on smart governance, multi-level governance, and social innovation, offering new perspectives on the role of communities in crisis management.

Based on these findings, governments must institutionalize smart communities in disaster response, ensuring direct access to resources, information, and decision-making processes. This requires the development of formal support mechanisms, ensuring that community networks have direct access to resources and information. Moreover, policies promoting digital infrastructure and real-time communication are vital to empowering community-led responses and improving disaster preparedness. Advancing decentralized governance, where communities have greater autonomy in coordinating local responses, can reduce over-reliance on state intervention and foster more resilient cities.

This study has some methodological limitations, including the lack of post-flood interviews, which could offer further insights into the long-term impacts of community-led governance. Additionally, quantitative research is needed to measure how smart communities contribute to urban resilience. Future studies should explore comparative analyses between Porto Alegre and other Latin American cities facing similar climate challenges to validate the framework in diverse contexts.

Another crucial area for further research is the vulnerable communities residing in high-risk areas, such as riverside settlements and hillside neighborhoods. Many of these groups faced forced displacement and difficulties in resettlement, exposing critical gaps in urban planning and disaster preparedness. Understanding how these communities organized themselves, accessed emergency support, and navigated institutional responses would provide valuable insights for developing more effective policies to prevent similar crises in the future.

In conclusion, this study emphasizes that urban resilience requires a collective effort, where governments, communities, and technologies collaborate to enhance disaster preparedness and recovery. The experience of Porto Alegre demonstrates that organized communities are strategic actors in disaster response. If cities aim to be better prepared for climate crises, they must embrace new governance models that balance citizen participation, technological innovation, and institutional support. Resilience is not just a theoretical concept, it is a practice built collectively.

Acknowledgement

References

Ação da Cidadania. (2024). Emergency shelters and food security response to the Porto Alegre floods. Porto Alegre, Brazil.

Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., & Airaksinen, M. (2017). What are the differences between smart, sustainable, and resilient cities? Cities, 60, 234–245. https://doi.org/10.1016/j.cities.2016.09.009

Alawadhi, S., Aldama-Nalda, A., Chourabi, H., Ramon, J., Leung, S., Mellouli, S., Nam, T., Pardo, T. A., Scholl, J., & Walker, S. (2017). Building understanding of smart city initiatives. In International Conference on Electronic Government (pp. 40–53). Springer. https://doi.org/10.1007/978-3-319-64677-0_4

Ariyaningsih, D., & Shaw, R. (2023). Community-based approach for climate resilience and COVID-19: Case study of a Climate Village (Kampung Iklim) in Balikpapan, Indonesia. Land, 12(3), 650. https://doi.org/10.3390/land12030650

Azizi, K., Kofi, S., Saija, L., Ghadir, M., & Meier, C. I. (2022). Urban climate-integrated community-based approaches to urban pluvial flooding research, trends, and future directions: A review. Urban Climate, 44, 101237. https://doi.org/10.1016/j.uclim.2022.101237

Baiocchi, G. (2003). Participation, activism, and politics: The Porto Alegre experiment and deliberative democratic theory. Politics & Society, 31(1), 43–72. https://doi.org/10.1177/0032329202250169

Bartoletti, R., & Faccioli, F. (2016). Public engagement, local policies, and citizens' participation: An Italian case study of civic collaboration. Social Media + Society, 2(3), 1–11. https://doi.org/10.1177/2056305116662187

Berardi, U. (2013). Sustainability assessments of urban communities through rating systems. Environment, Development and Sustainability, 15(6), 1573–1591. https://doi.org/10.1007/s10668-013-9462-0

Caragliu, A., Del Bo, C., & Nijkamp, P. (2011). Smart cities in Europe. Journal of Urban Technology, 18(2), 65–82. https://doi.org/10.1080/10630732.2011.601117

Craig, G., Mayo, M., Popple, K., Shaw, M., & Taylor, M. (2004). The Budapest Declaration: Building European civil society through community development. Community Development Journal, 39(4), 423–429. https://doi.org/10.1093/cdj/39.4.423

Development Bank of Latin America (CAF). (2014). Climate change and cities in Latin America: Vulnerability and adaptation. CAF Development Bank.

DRRS Porto Alegre. (2024). Final report on disaster response and resilience strategies in Porto Alegre: Lessons from the 2024 floods. Porto Alegre, Brazil.

Fundação Cultural Floresta. (2024). Emergency relief and social mobilization in disaster-affected communities: Response to the Porto Alegre floods of 2024. Porto Alegre, Brazil.

Governo do Rio Grande do Sul. (2024). Relatório de impacto das enchentes de 2024: Infraestrutura, realocação e planejamento urbano. Porto Alegre, Brazil.

Goldfrank, B. (2011). Deepening local democracy in Latin America: Participation, decentralization, and the left. Penn State Press.

Harrison, C., & Donnelly, I. A. (2011). A theory of smart cities. In Proceedings of the 55th Annual Meeting of the International Society for the Systems Sciences (pp. 1–15).

Hautekeur, G. (2005). Community development in Europe. Community Development Journal, 40(4), 385–398. https://doi.org/10.1093/cdj/bsi059

Janssen, M., Charalabidis, Y., & Zuiderwijk, A. (2012). Benefits, adoption barriers and myths of open data and open government. Information Systems Management, 29(4), 258–268. https://doi.org/10.1080/10580530.2012.716740

Komninos, N. (2013). Intelligent cities: Towards interactive and global innovation environments. Routledge. https://doi.org/10.4324/9780203072558

Li, H., Zhang, X., & Fan, J. (2020). The impact of urbanization on extreme precipitation events: Evidence from high-resolution climate models. Journal of Climate Change Research, 15(4), 112-127. https://doi.org/10.1016/j.jccr.2020.03.005

Lopes, C. T., Luciano, E., & Roldan, L. (2024). How Communities Become Smart: A Case Study of Porto

Alegre, Brazil. In Proceedings of the 25th Annual International Conference on Digital Government Research (dg.o '24) (pp. 832–840). Association for Computing Machinery, New York, NY, USA. https://doi.org/10.1145/3657054.3657267

Marasco, S., Kammouh, O., & Cimellaro, G. P. (2022). Disaster resilience quantification of communities: A risk-based approach. International Journal of Disaster Risk Reduction, 70, 102778. https://doi.org/10.1016/j.ijdrr.2022.102778

McKinsey Global Institute. (2011). Urban world: Mapping the economic power of cities. McKinsey & Company.

Mutiarni, Y. S., Nakamura, H., & Bhattacharya, Y. (2022). The resilient community: Strengthening people-centered disaster risk reduction in the Merapi volcano community, Java, Indonesia. Sustainability, 14(6), 2215. https://doi.org/10.3390/su14062215

Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. In Proceedings of the 12th Annual International Conference on Digital Government Research (pp. 282–291). https://doi.org/10.1145/2037556.2037602

Nasiri, H., Yusof, M. J. M., & Ali, T. A. (2016). An overview of flood mitigation strategy and assessment of dam operation for flood control. Water Resources Management, 30(3), 925–945. https://doi.org/10.1007/s11269-015-1191-6

Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2020). Flooding and flood risk reduction in Nigeria: A review of the role of the government. Environmental Management, 66(4), 719–733. https://doi.org/10.1007/s00267-020-01305-2

Parvin, G. A., Dasgupta, R., Abedin, A., Ingirige, B., Kibria, M. G., Fujita, K., Basu, M., Shaw, R., & Nakagawa, H. (2023). Disaster experiences, associated problems, and lessons in Southwestern Coastal Bangladesh: Exploring through participatory rural appraisal to enhance resilience. Sustainable and Resilient Infrastructure, 8(2), 223–236. https://doi.org/10.1080/23789689.2022.2107728

Pereira, G. V., Macadar, M. A., Luciano, E. M., & Testa, M. G. (2017). Delivering public value through open government data initiatives in a smart city context. Information Systems Frontiers, 19(2), 213–229. https://doi.org/10.1007/s10796-016-9673-7

Phong, T. V. G., & Shaw, R. (2009). Enhancing community resilience through information management: Flood risk. In Geoinformatics for Natural Resource Management (pp. 165–183). Nova Science Publishers.

Prefeitura de Porto Alegre. (2024a). Plano emergencial de resposta às enchentes: Estratégias de resiliência urbana e coordenação interinstitucional. Porto Alegre, Brazil.

Prefeitura de Porto Alegre. (2024b). ObservaPOA: Análise de dados sobre a resposta comunitária e institucional às enchentes de 2024. Porto Alegre, Brazil.

Reardon, K. M., & Forester, J. (2015). Rebuilding community after Katrina: Transformative community planning and action. Planning Theory & Practice, 16(3), 305–324. https://doi.org/10.1080/14649357.2015.1056633

Rozer, V., Vogel, C., & Costa, L. (2021). Flood risks and urban expansion: Understanding vulnerabilities in changing cities. Environmental Hazards, 20(3), 275–289. https://doi.org/10.1080/17477891.2021.1905568

Shastri, H., Ghosh, S., Paul, S., & Karmakar, S. (2015). Urban heat island intensity over major cities of India: Spatial and temporal variations. Journal of Earth System Science, 124(2), 499–514. https://doi.org/10.1007/s12040-015-0548-4

Tang, J. (2022). Design and research of intelligent community management system based on intelligent Internet of Things. Mobile Information Systems, 2022, 1–8. https://doi.org/10.1155/2022/9874056

Tedong, P. A., & Zyed, A. S. (2021). Searching for sustainable cities: Residents' perceptions on the implementation of sustainable cities in Malaysia. Community Development Journal, 56(1), 101–118. https://doi.org/10.1093/cdj/bsz027

United Nations (UN). (2024). Flooding in southern Brazil: Climate change, El Niño, and urban resilience

strategies. https://news.un.org/pt/story/2024/05/1831311

United Nations. (2019). World urbanization prospects: The 2018 revision. Department of Economic and Social Affairs, Population Division. https://population.un.org/wup/

UN-Habitat. (2022). World cities report 2022: Envisaging the future of cities. United Nations Human Settlements Programme.

World Meteorological Organization (WMO). (2024). State of the climate in Latin America and the Caribbean 2023. WMO. https://public.wmo.int/en/resources/state-of-climate

Appendix A

What is your vision regarding the 4th District development process?

What short-term and long-term results are expected with the implementation of +4D?

Are there specific strategies to promote social inclusion and generate employment for citizens?

How is the local community involved in the development process?

Are there specific forums or channels for residents' participation in decision-making?

How does the program collect feedback and address the needs of residents?

What are the transparency and accountability mechanisms to inform residents about decisions and allocated resources?

Is there any incentive to encourage civic engagement among residents?

What is the role of civil society in district planning?

What are the main benefits for the government in actively including communities (small governance) in Master Plans?

How are challenges of representativity and diversity addressed when including these communities in governmental planning processes?

What are the main barriers faced by citizens when trying to participate in these plans and solutions?

What is the importance of ongoing collaboration between the government and communities in building "smart city" strategies?

Should there be a more consistent approach to active public listening in the development of these plans?

How do you anticipate the evolution of citizen participation considering innovations, not only in data collection but in general collab?

How does the government establish contact and involve these groups in the development of these plans?