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SMART CITIES AND URBAN RESILIENCE: PREPARING FOR THE FUTURE OF CLIMATE CHANGE

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ABSTRACT
The article investigates the role of smart cities in building urban resilience in the face of climate change. The general objective is to analyze how technologies applied in smart cities can strengthen the capacity of urban areas to respond to climate challenges. Specific objectives include: exploring technologies applied to increase urban resilience; identify challenges and opportunities in vulnerable areas, and evaluate effective urban planning and governance models. The research was based on an integrative literature review of works published between 2004 and 2024. During the study, it was observed that technologies such as the Internet of Things (IoT), big data, and smart grids play a crucial role in urban resilience, enabling real-time monitoring of environmental conditions and effective mitigation of emergencies. However, challenges such as inequality in access to these technologies and the need for robust regulation to ensure cybersecurity were highlighted. The paper concludes that while smart city technologies offer great potential to increase urban resilience, they need to be accompanied by inclusive and collaborative public policies to ensure that their benefits are widely distributed. Future studies may focus on the creation of participatory governance models, among others.

Keywords: Smart Cities. Urban Resilience. Climate Change. Climate Governance.

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INTRODUCTION

In recent years, the concept of "smart cities" has stood out as an innovative and essential approach to addressing contemporary urban challenges. A city is characterized as smart, by the intensive use of digital technologies and data to optimize resource management, improve quality of life and promote sustainability (Axhausen et al., 2012).

The accelerated growth of cities and the effects of climate change have put to the test the conventional ways of planning and managing urban centers, making it essential to search for new solutions that combine technological progress and environmental preservation.

Recent studies indicate that the synergy between technological solutions and resilience strategies can strengthen the capacity of cities to face climate challenges, promoting not only adaptation to change, but also the mitigation of their impacts. In addition, data-driven urban planning and the integration of nature-based solutions can contribute significantly to the creation of more resilient urban environments (Mcphearson et al., 2016).

With climate change posing increasing risks to urban infrastructure, public health, and the economy, there is an urgent need to develop and implement technological solutions that can anticipate and mitigate its effects. (Smith, Jones, 2023). Early warning systems, smart *grids*, sustainable urban mobility, and digital initiatives in public administration are some examples of technological innovations that can significantly contribute to the resilience of cities in the face of climate impacts.

However, urban resilience cannot be achieved with technology alone; active community participation and inclusive planning are equally critical (Da Silva et al., 2024). Therefore, while several cities around the world are adopting innovative strategies to improve both their infrastructure and the quality of services offered to citizens, there are still significant challenges to overcome to integrate these technologies into truly effective climate resilience practices.

Therefore, a study that contributes to the understanding of the synergies between technology and urban planning is relevant, offering valuable *insights* for managers, planners, and researchers interested in developing more resilient and adaptive cities.

In this context, through an integrative review of the existing literature, this article aims to investigate how smart cities can contribute to urban resilience in the face of climate change, in order not only to improve efficiency and quality of life in cities, but also to

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strengthen the capacity of these cities to face the impacts of climate change. More specifically, the article seeks to analyze how smart city technologies are being applied to increase urban resilience; identify the main challenges and opportunities in the implementation of smart solutions in urban areas vulnerable to climate change to evaluate the models of governance and urban planning that are most effective in integrating smart city technologies with climate resilience.

This article is divided into 4 sections: section 1, where the methodology used in the development of the research is presented; section 2, where the literature review is carried out; section 3, where the results and discussion are presented; finally, in section 4, the conclusion of the research is presented.

METHODOLOGY

The present study is a bibliographic research with a qualitative approach of the integrative review type, focused on the theme "Smart Cities and Urban Resilience: Preparing for the Future of Climate Change". The method used allows a synthesis of existing knowledge and the integration of the results obtained for its practical application.

To carry out this study, the following steps were followed: definition of the guiding questions, definition of the research objectives, definition of the inclusion and exclusion criteria of the documents, definition of the information to be extracted from the research, screening of the documents in the literature, search and selection methodology, analysis of the results and, finally, discussion of the findings and presentation of the review.

The guiding questions of the survey were: "How are smart city technologies being applied to increase urban resilience? What are the main challenges and opportunities to implement smart solutions in urban areas vulnerable to climate change? Which models of governance and urban planning are most effective in integrating smart cities and climate resilience?"

These questions guided the formulation of the general objective and specific objectives of the review, which aimed to investigate the contribution of smart city technologies to urban resilience, identify challenges and opportunities in the implementation of these solutions in vulnerable areas, and analyze the most effective governance and planning models.

The criteria for inclusion and exclusion of the documents were clearly established. Documents addressing smart city technologies, urban resilience, climate change, and governance and urban planning models, published between 2004 and 2024, were included. On the other hand, doctoral theses, master's dissertations, monographs, journalistic articles, and audio and video documents were excluded.

For data collection, relevant information was extracted about technological applications for urban resilience, the challenges and opportunities in the implementation of smart solutions, and urban governance and planning models. The selection of documents was carried out between August and September 2024. The online databases of *Elsevier Science's Mega Source (ScienceDirect), Wiley Online Library, Institute of Electrical and Electronics Engineers* (*IEEE Xplore*), *Sage Journals, SpringerLink* were used. The descriptors used in the search included terms such as "Smart Cities", "Urban Resilience" and "Climate Change", combined in some databases with the Boolean operator AND to refine the search. Language filters (English and Portuguese) and year of publication were also applied.

The search and selection procedures resulted in different volumes of documents for each database. In *ScienceDirect*, the initial search generated 328 documents; after applying the exclusion criteria and analyzing the abstracts, 18 articles were chosen. In *Wiley Online Library*, of the 36 documents retrieved, 12 were filtered, resulting in the selection of 2 articles. At the *Institute of Electrical and Electronics Engineers* (*IEEE Xplore*), 158 articles were found, of which 17 passed the applied filters and 7 were selected after analysis of the abstracts. In *Sage Journals*, 38 documents were found, with 15 selected after filters and analysis of the abstracts, of which 5 were chosen for detailed analysis. In *SpringerLink* , 310 articles were found, of which 62 were filtered and 4 were selected for detailed analysis.

In addition to the search in the aforementioned databases, 5 articles and 1 book chapter located through exploratory research on an online platform were also used, in addition to 6 government websites.

The analysis of the results involved the evaluation of the contributions of the selected documents and the projects applied in the cities to the understanding of smart city technologies, the challenges and opportunities in vulnerable areas and the models of governance and urban planning. The analysis provided a synthesis of the main findings in different approaches found in the literature and in the context of the cities analyzed.

The review was structured to offer a consolidated view of the topic addressed. The final sample for analysis consisted of 48 documents, 18 from *ScienceDirect*, 2 from *the*

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Wiley Online Library, 7 from the *Institute of Electrical and Electronics Engineers*, 5 from *Sage Journals*, 4 from SpringerLink, 5 articles and 1 chapter of an exploratory research book, which were reviewed and analyzed in detail, in addition to 6 government websites.

LITERATURE REVIEW

HOW ARE SMART CITY TECHNOLOGIES BEING APPLIED TO INCREASE URBAN RESILIENCE?

Urban resilience, defined as the ability of cities to resist, adapt to, and recover from adverse events, is increasingly relevant in the context of climate change (Leichenko, 2011). Extreme events such as floods, heat waves, and intense storms are becoming more frequent and severe due to changes in the global climate (IPCC, 2021), making urban resilience a central concept in the planning and management of contemporary cities, requiring new governance models that prioritize adaptation and mitigation in the face of environmental challenges (Evans, 2011).

At the same time, smart cities, by strategically integrating digital technologies, offer innovative solutions to improve urban efficiency and sustainability, while strengthening cities' ability to adapt to emerging environmental challenges (Kitchin, 2014).

One of the most widely applied technologies in the context of smart cities is the Internet of Things (IoT), which involves the interconnection of devices through sensors that collect and transmit data in real time. The Internet of Things (IoT) makes it possible to create integrated urban systems that continuously monitor critical variables such as water levels, air quality, and temperature (Da Silva et al., 2024).

These continuous monitoring systems are essential for increasing urban resilience, as they allow local authorities to quickly identify potential threats and implement mitigation measures (Ahern, 2011). In flood-prone cities, especially in coastal or low-lying areas, IoT sensors are often installed in watersheds to monitor water levels. When these levels exceed a predefined threshold, authorities can issue early warnings to the public and coordinate emergency responses, thereby helping to mitigate flood impacts (Chen et al., 2022).

IoT has also been applied to optimize the management of critical infrastructures, such as energy and transportation networks, increasing their resilience to disasters and disruptions, through advanced monitoring and control systems (Chlamtac et al., 2012). In addition, the potential of the Internet of Things is amplified when combined with the use of *big data. Big data* refers to the collection and analysis of large volumes of data from multiple sources, including urban sensors, social media data, weather systems, and disaster histories (Chen et al., 2014).

The use of *big data* to analyze patterns of risk and vulnerability has been instrumental in improving urban resilience, enabling informed decision-making based on concrete evidence (Kitchin, 2014). Access to historical data and future climate modeling is crucial to enable cities to more accurately project the likelihood of climate disasters and develop adaptation strategies to protect the most vulnerable (IPCC, 2014).

In addition, the use of machine learning techniques makes it possible to create more accurate predictive models. These models are able to predict, in advance, how climate change and other environmental factors may impact infrastructure and urban populations, providing cities with the ability to adapt their policies and responses in real-time (Bonsall et al., 2019).

Similarly, smart *grids* are a key component of smart cities, as they play a crucial role in urban resilience. These networks utilize advanced sensors and prediction algorithms to quickly detect power outages and areas of failure. During extreme weather events, this technology allows the grid to respond automatically, redirecting power to unaffected areas and minimizing the extent of blackouts. By quickly isolating damage, *smart grids* also prevent the ripple effect, in which local faults can spread to wider regions of the city (Amin, 2011; Das et al., 2020).

In addition to isolating damage, *smart grids* also facilitate the integration of distributed energy sources, such as solar and wind power. This flexibility is critical during natural disasters, especially when centralized energy infrastructure suffers significant damage. The ability to quickly integrate distributed energy sources allows critical areas such as hospitals and emergency control centers to continue functioning even if the main grid is out of operation (Mancarella, Panteli, 2017).

Post-disaster recovery is also facilitated by *smart grids*, as this type of network provides a detailed view of damaged infrastructure and indicates priority areas for repair, allowing maintenance teams to be directed efficiently, restoring power faster compared to traditional grids (Fang et al., 2012).

Finally, *smart grids* also play a key role in communicating with the population during emergencies, as they allow the dissemination of information about power outages, status updates, and safety instructions directly to citizens, helping to ensure that the population is

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informed and prepared, minimizing risks and ensuring a more organized response to crisis situations (Farhangi, 2010).

In addition to *smart grids*, another essential infrastructure in times of crisis are urban transport systems. Smart city technologies applied to urban transport make it possible to optimize traffic flow, identify alternative routes during emergencies, and ensure that transport infrastructures are restored quickly after disasters. Road-mounted sensors, for example, can monitor traffic volume and adjust traffic lights automatically to reduce congestion in crisis situations (Al-Hattab et. al., 2024).

In addition, drones offer comprehensive coverage for monitoring, reaching remote areas and collecting real-time data that can be analyzed to implement preventive actions or carry out interventions, when necessary. During the COVID-19 pandemic, smart cities used drones to deliver medical supplies to isolated areas and monitor adherence to social distancing measures (Aujla et. al, 2022). This use of technology not only helped in the management of the immediate crisis, but also demonstrated the potential of drones in strengthening urban resilience and public health management.

WHAT ARE THE MAIN CHALLENGES AND OPPORTUNITIES TO IMPLEMENT SMART SOLUTIONS IN URBAN AREAS VULNERABLE TO CLIMATE CHANGE?

In recent times, technologies have helped warn people about the onset of floods and other climate disasters. However, the adoption of these technologies faces significant obstacles that can limit access to and ability to implement smart solutions (Brakenridge, Groeve, Kugler, 2007; Ma, 2021).

One of the main barriers to the implementation of smart solutions in urban areas vulnerable to climate change is inequality in access to technologies and economic resources (Aghajani, Ghadimi, 2018). While cities in developed countries are adopting smart technologies to address urban challenges, many areas in developing countries face significant constraints in terms of funding and technical capacities, which can increase social inequalities and leave the most vulnerable populations even more exposed to the impacts of climate change (Graham, Shelton, 2013).

Moreover, even in cities that have access to advanced technologies, the costs of installing and maintaining smart infrastructures can be prohibitive (Kitchin, 2014). The need for public-private partnerships to make these projects feasible is essential, but also

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complex, as it requires a clear division of responsibilities and the creation of incentives to attract private investment in urban areas of high vulnerability (Axhausen et al., 2012).

Another significant challenge in implementing smart solutions for urban resilience is the issue of cybersecurity. As cities become more interconnected, with a greater reliance on digital systems for the management of critical infrastructures, the risk of cyberattacks that can compromise these infrastructures increases. IoT systems, *smart grids*, and digital governance platforms are particularly exposed to security vulnerabilities, which requires robust regulation and strategies to protect against cyber threats (Almeida, 2023; Andrade, Tello-Oquendo, Ortiz, 2021).

In addition to cybersecurity, citizens' privacy also becomes a concern. Smart city technologies rely on the collection of large volumes of personal data, which raises questions about how this information is stored, processed, and shared. Implementing strict privacy policies and involving citizens in the decision-making process about the use of their data are important steps in ensuring that smart cities are safe and reliable (Braun et. al, 2018).

However, many cities, especially in developing countries, face the challenge of urban infrastructure that is obsolete or is not designed to cope with the impacts of climate change and population growth. In these cases, the mere adoption of smart technologies may not be enough to ensure urban resilience. It is essential to invest first in the modernization and adaptation of existing infrastructure so that it can effectively support technological solutions (Bibri, Krogstie, 2020).

For example, implementing smart energy grids in a city with an old power grid may be ineffective if that grid is not retrofitted to support the new technology (Amin, 2011; Das, et al., 2020). Similarly, intelligent transport systems require adequate road infrastructure, which can be a major obstacle in cities with poorly planned or congested streets (Al-Hattab et. al., 2024). The adaptability of urban infrastructures, therefore, must be a priority so that smart city technologies can be implemented effectively and sustainably (Axhausen et al., 2012).

Notoriously, the effective implementation of smart solutions requires robust coordination between various levels of government, social sectors, and private initiatives (Nam, Pardo, 2011). However, the lack of integrated governance and institutional fragmentation often prevent the successful implementation of these solutions. Cities constantly face governance challenges where disparate departments operate in silos, complicating the development of a cohesive and collaborative approach to urban resilience (Chourabi, et al., 2012).

In addition, smart cities must be inclusive and participatory, involving all stakeholders, especially vulnerable communities, in the decision-making process. In particular, in the context of climate change, it is crucial to ensure that the most affected populations have a meaningful voice in the formulation of adaptation policies and strategies (Anguelovski et al., 2016; Anguelovski, Carmin, Roberts, 2014; Broto, 2017).

On the other hand, the implementation of smart solutions in cities presents several opportunities to address contemporary urban challenges, such as growing urbanization, the need for sustainability, and the impacts of climate change.

Technologies such as the Internet of Things (IoT), *big data* , and artificial intelligence (AI) have the potential to transform urban management, allowing for more efficient management of resources such as energy, water, and transportation, while reducing costs and improving the quality of life for citizens (Adewole et al. 2016; Batty, 2018; Bui et al., 2014).

Smart energy grids, for example, allow the integration of renewable sources, such as solar and wind energy, promoting a transition to more sustainable and resilient cities (Albuyeh, Ipakchi, 2009). In addition, the use of intelligent systems for real-time data monitoring and analysis facilitates response to natural disasters and decision-making based on concrete evidence, which can save lives and mitigate damage (Axhausen et al., 2012).

Thus, smart solutions represent an opportunity not only to optimize urban infrastructure, but also to increase the resilience of cities in the face of the environmental and social challenges of the future.

Public-private partnerships have proven to be one of the most effective strategies to enable the implementation of smart technologies in vulnerable urban areas. Collaboration between governments, technology companies, and universities allows for the sharing of resources, expertise, and innovation. These partnerships can be particularly useful in implementing *smart grid,* IoT, and *big data* systems, which require significant upfront investment but offer long-term benefits in terms of urban resilience and sustainability (Greve, Hodge, 2007; Solheim, Quan, 2023).

In addition, social innovation has become a powerful tool to mobilize communities and sectors of civil society in the implementation of smart solutions. Social innovation

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initiatives focus on creating technological solutions that respond directly to the needs of local communities, often combining technology with traditional resilience practices (Mulgan, 2006). In vulnerable urban areas, these initiatives can be essential to ensure that technological solutions are accessible and effective.

Another important opportunity for the implementation of smart solutions is the integration of smart city technologies with nature-based solutions (NBS), which are urban planning strategies that use natural ecological processes to increase the resilience of cities. Solutions such as urban parks, green roofs, and sustainable drainage infrastructure can be combined with digital monitoring technologies to create an urban system that is more resilient and adaptable to climate change (Kabisch et al., 2016).

For example, in flood-prone cities, IoT technologies can be used to monitor the performance of natural drainage systems such as *wetlands* or retention basins, helping to optimize their effectiveness and ensuring that they are able to handle large volumes of water during storms (Haynes, Hehl-Lange, Lange, 2018). Combining nature-based solutions with smart technologies can also reduce the cost of traditional infrastructure, as well as promote biodiversity and improve urban quality of life (Bendor et al., 2015).

In addition, the transition to renewable energy sources is another crucial opportunity, where smart cities can contribute significantly to climate resilience. Smart city technologies enable the efficient integration of energy sources such as solar, wind, and geothermal into urban power grids. In addition, energy storage systems, such as large-scale batteries, can be used to ensure that energy is available even during extreme weather events that affect conventional power generation (Amin, 2011; Das, et al., 2020).

The adoption of electric vehicles and the implementation of smart charging networks in cities also have the potential to increase urban resilience, by reducing dependence on fossil fuels and creating a more sustainable and adaptable transport system to climate change. Cities such as Oslo and Copenhagen are already at the forefront of this transition, implementing smart solutions for energy management and sustainable urban mobility (Geels, Frank et al., 2018; Sovacool et al., 2018).

WHICH MODELS OF GOVERNANCE AND URBAN PLANNING ARE MOST EFFECTIVE IN INTEGRATING SMART CITIES AND CLIMATE RESILIENCE?

Growing urbanization and the intensification of the impacts of climate change on cities require new models of governance and urban planning. Governments, civil society, and the private sector need to collaborate to ensure that technological innovations bring inclusive and sustainable solutions.

Governance is key to the development of resilient cities. It involves creating a framework that integrates climate policies into long-term urban planning, ensuring that smart city solutions are aligned with climate change mitigation and adaptation. A clear example of this model is presented by ICLEI - Local Governments for Sustainability, which proposes an articulated governance between different areas and sectors, from an executive perspective (ICLEI, Sustainable Cities Program, 2016).

This governance model is based on climate change forums or committees that promote dialogue between key actors, such as universities, NGOs, government, and the private sector. Strengthening collaboration between these actors is essential to develop coordinated actions that integrate technology into cities, keeping climate resilience as a central focus (ICLEI, Sustainable Cities Program, 2016).

In cities like Recife, for example, climate governance includes the Sustainability and Climate Change Committee (COMCLIMA) and the Executive Group on Sustainability and Climate Change (GECLIMA). These groups coordinate public policies aimed at mitigating and adapting to climate change, encouraging the use of smart technologies to improve urban infrastructure (Recife, 2020). Strengthening this collaborative governance allows cities to advance the adoption of smart technologies while preparing for extreme weather events.

Integrating smart city technologies into urban planning requires an approach that addresses both technological innovation and environmental and social resilience. Cities such as Recife, Fortaleza, and Salvador have adopted climate action plans that integrate nature-based solutions and technological innovations in tackling climate change. These plans provide a clear roadmap for reducing greenhouse gas (GHG) emissions and increasing resilience to climate events such as floods and heatwaves (Fortaleza, 2020; Recife, 2020; Salvador, 2020).

The Recife Local Climate Action Plan (PLAC) is an example of urban planning that aims to align the city with the commitments of the Paris Agreement, adopting goals for carbon neutrality by 2050. PLAC was built on participatory governance, involving various sectors of society and promoting the use of sustainable technologies, such as solar energy systems and smart *grids*. In addition, the plan takes a holistic approach by including

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climate justice initiatives, which ensure that the most vulnerable populations are prioritized in mitigation and adaptation strategies (Recife, 2020).

Another relevant example is the Fortaleza Climate Action Plan, which also adopts an integrated approach to urban planning and resilience. The city has focused on low-carbon solutions and innovative technologies to reduce its emissions, promote sustainable mobility, and increase energy efficiency. The Fortaleza plan establishes the importance of partnerships between the government, academia, and the private sector to boost the adoption of smart technologies in areas such as transportation and energy (Fortaleza, 2020).

As already discussed, smart cities use technologies such as sensors, data networks, and digital infrastructure to monitor and optimize the use of resources. However, these innovations need to be implemented in a way that also promotes urban resilience. In Recife, for example, the PLAC includes specific targets to ensure that all of the city's electricity comes from renewable sources by 2037, using smart technologies to monitor and optimize energy use. In addition, the plan includes the implementation of *smart grids* to make energy distribution more efficient and resilient (Recife, 2020).

The concept of nature-based solutions (NBS) also plays a crucial role in integrating smart technologies and climate resilience. These solutions include creating green infrastructure, such as rain gardens and green roofs, that help mitigate the effects of climate change, such as flooding, while improving the quality of urban life (Recife, 2020). NBS are particularly effective when combined with smart technologies, which can monitor the performance of these solutions and ensure their long-term effectiveness.

In addition, the green economy, which encompasses activities such as recycling and renewable energy generation, is being driven by smart technologies in cities. The "Recife City of Energy Efficiency" project exemplifies how the use of smart technologies can reduce energy consumption and carbon emissions, aligning urban development with long-term climate goals (Recife, 2020).

Integrating smart city technologies with climate resilience requires innovative governance models and adaptive urban planning. Cities such as Recife and Fortaleza demonstrate that it is possible to adopt a strategic plan that prioritizes both technological innovation and social and environmental resilience. Participatory and collaborative governance is essential to ensure that technological innovations are applied in an inclusive

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manner, benefiting all layers of society and preparing cities to face the climate challenges of the future (ICLEI, Sustainable Cities Programme, 2016; Fortaleza, 2020; Recife, 2020).

RESULTS AND DISCUSSION

The results presented in the study on the integration of smart cities with urban resilience in the face of climate change reveal the central role that technologies play in urban adaptation to environmental risks. The use of smart technologies, such as the Internet of Things (IoT) and *smart grids*, emerge as an essential component for efficient urban crisis management, enabling rapid responses to climate disasters and optimizing the distribution of resources.

According to Axhausen et al. (2012), smart cities are using technological solutions to improve urban management in an efficient way, using sensors and communication networks to monitor and adjust urban infrastructure systems. The Internet of Things, in particular, allows for real-time data collection, and is key to increasing urban resilience. Zook et al. (2010) highlight the importance of monitoring systems to predict floods and other environmental crises, which allows for an immediate response from the authorities.

However, the challenges to implementing smart solutions in vulnerable areas are considerable. Graham and Shelton (2013) point out that, although technologies advance in cities in developed countries, in developing countries, cities face economic and technical barriers to adopt these innovations. In addition, Kitchin (2014) points out that, even in cities with access to these technologies, the high cost of installation and maintenance can be prohibitive, which prevents their adoption on a large scale.

Nevertheless, with cities becoming more interconnected, as addressed by Almeida (2023), Andrade et. al. (2021) and Braun et. al (2018), they become potential targets of cyberattacks, arising challenges related to cybersecurity and privacy of citizens' data.

Another challenge is the obsolete infrastructures present in cities. Bibri and krogstie (2020) emphasize that the adoption of innovative technological solutions alone is not enough to ensure urban resilience.

Institutional fragmentation is another challenge pointed out where, as addressed by Chourabi et. al. (2012), the lack of dialogue between the departments involved prevents the successful implementation of technological solutions.

Although the adoption of smart technologies has challenges, according to Adewole (2016), Batty (2018) and Bui (2014) they are an opportunity for cities to optimize the management of urban resources and improve the quality of life of the population.

As highlighted by Axhausen et al. (2012), *smart grids* , by integrating renewable sources, offer an opportunity to make cities, in addition to being resilient, more sustainable.

Based on the ideas of Greve and Hodge (2007) and Solheim and Quan (2023), the study pointed to public-private partnerships as a way to enable the implementation of smart technologies. The authors also emphasize the importance of sharing resources, technical expertise and technological innovations between governments, universities and private companies as a way to make implementation viable.

In addition, as emphasized by Mulgan (2020), social innovation has become a powerful tool in the implementation of technological solutions, as they focus on creating solutions that directly respond to the needs of the population.

Another opportunity discussed in the study is the integration of smart technologies with nature-based solutions. As pointed out by Kabisch, et al. (2016), this approach can create more resilient systems adapted to climate change.

A crucial point debated is the need for efficient and integrated governance so that cities can fully enjoy the benefits of smart technologies. Evans (2011) argues that new governance models, which prioritize climate resilience and adaptation, are essential for the success of these initiatives.

When discussing governance models, the Local Climate Action Guide (ICLEI, Sustainable Cities Program, 2016) highlights the collaborative governance model adopted in cities such as Recife, which includes collaborative forums between government, civil society, and the private sector to promote more integrated and sustainable urban policies.

It was addressed in the study that the cities of Recife, Fortaleza and Salvador incorporated integrative governance in their climate action plans, thus focusing on the integration of smart technologies with urban planning, and contemplating both innovation and environmental and social resilience, contributing significantly to the mitigation of the effects of climate change.

Another governance model explored in the research was participatory and collaborative governance, which is essential to ensure that the population is heard and contributes to the formulation of public policies and adaptation and mitigation strategies, while also ensuring that the most vulnerable population has priority.

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In summary, the research shows how effective collaborative, integrative and participatory governance models are in the formulation of public policies aimed at climate change adaptation and mitigation.

CONCLUSION

The study highlights that technologies are essential to help cities face climate change, as they enable real-time monitoring of environmental conditions and the collection of data for informed decisions.

Opportunities were identified for the implementation of smart solutions in vulnerable urban areas, such as public-private partnerships and the integration of nature-based solutions with digital technologies. These actions increase the capacity to mitigate climate effects by offering sustainable alternatives. However, challenges persist, such as inequality in access to financial and technological resources, especially in developing countries, as well as cybersecurity and data privacy concerns, which require adequate regulations.

The study underscored the importance of effective governance and urban planning models to integrate smart city technologies with climate resilience, involving governments, the private sector, and civil society. Cities such as Recife and Fortaleza were cited as examples of governance models and efficient urban planning.

Although the study presents an optimistic view, it is essential that technological advances are accompanied by robust public policies that ensure equity in access and protect data.

Future research can deepen the analysis of practical cases of implementation of technological solutions in developing countries.

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