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SMART CITIES SOLUTIONS FOR RESILIENCE IN DEVELOPING COUNTRIES: POTENTIAL BENEFITS AND IMPLEMENTATION CHALLENGES (SESSÃO TEMÁTICA 6 - NATUREZA, CRISE AMBIENTAL E MUDANÇAS CLIMÁTICAS)

Hélio Munhoz Buba[1]
USP/Esalq | heliomububa@gmail

Sessão Temática 6: Natureza, Crise Ambiental e Mudanças Climáticas

Abstract: Smart Cities, a concept which incorporates information and communication technologies to urban development, planning and policies has increased importance as it enables cities to perform better in different aspects of everyday life, such as environment, basic services and governance. However, most smart city research focuses on developed countries and flagship solutions, while the global south states are the ones urbanizing the most and suffering more impacts from natural hazards in their cities. This paper investigates the interface between smart cities and urban resilience in developing countries and evaluates how they are applied to avoid losses of lives, infrastructure, livelihood and capital. This research was written based on case studies, reports, academic papers and literature reviews. The results show that there are benefits of using smart cities solutions when dealing with natural disaster preparedness, response and recovery in developing countries if tailored to local context, community-based and focused on long-term sustainability.

Keywords: resilience; climate change; smart cities; global south; DRR.

[1] Arquiteto e urbanista pela Universidade Federal do Paraná, mestre em Cooperação Internacional, Finanças e Desenvolvimento pela Universita Degli Studi Di Roma Unitelma Sapienza e pós-graduando USP/Esalq em Data Science e Analytics

SOLUÇÕES DE CIDADES INTELIGENTES PARA A RESILIÊNCIA EM PAÍSES EM DESENVOLVIMENTO: POTENCIAIS BENEFÍCIOS E DESAFIOS DE IMPLEMENTAÇÃO

Resumo: *Cidades Inteligentes, um conceito que incorpora tecnologias de informação e comunicação ao desenvolvimento urbano, planejamento e políticas, tem ganhado importância à medida que permite que as cidades apresentem melhor desempenho em diferentes aspectos do dia a dia, como meio ambiente, serviços básicos e governança. No entanto, a maior parte das pesquisas sobre cidades inteligentes concentra-se em países desenvolvidos e soluções de referência, enquanto os países do sul global são os que mais estão se urbanizam e vêm sofrendo maiores impactos de desastres naturais em suas cidades. Este artigo investiga a interface entre cidades inteligentes e resiliência urbana em países em desenvolvimento e avalia como essas abordagens são aplicadas para evitar perdas de vidas, infraestrutura, meios de subsistência e capital. Esta pesquisa foi elaborada com base em estudos de caso, relatórios, artigos acadêmicos e revisões de literatura. Os resultados mostram que há benefícios no uso de soluções de cidades inteligentes no preparo, resposta e recuperação de desastres naturais em países em desenvolvimento, desde que sejam adaptadas ao contexto local, baseadas na comunidade e focadas na sustentabilidade a longo prazo.*

Palavras-chave: *resiliência; mudanças climáticas; cidades inteligentes; sul global; DRR.*

SOLUCIONES DE CIUDADES INTELIGENTES PARA LA RESILIENCIA EN PAÍSES EN DESARROLLO: BENEFICIOS POTENCIALES Y DESAFÍOS DE IMPLEMENTACIÓN

Resumen: *Ciudades Inteligentes, un concepto que incorpora tecnologías de información y comunicación al desarrollo urbano, la planificación y las políticas, ha ganado importancia en la medida en que permite que las ciudades tengan un mejor desempeño en diferentes aspectos de la vida cotidiana, como el medio ambiente, los servicios básicos y la gobernanza. Sin embargo, la mayor parte de las investigaciones sobre ciudades inteligentes se concentra en países desarrollados y soluciones de referencia, mientras que los países del sur global son los que más se están urbanizando y han sufrido mayores impactos de desastres naturales en sus ciudades. Este artículo investiga la intersección entre ciudades inteligentes y resiliencia urbana en países en desarrollo y evalúa cómo estas estrategias se aplican para evitar pérdidas de vidas, infraestructura, medios de subsistencia y capital. Esta investigación se elaboró con base en estudios de caso, informes, artículos académicos y revisiones de literatura. Los resultados muestran que existen beneficios en el uso de soluciones de ciudades inteligentes para la preparación, respuesta y recuperación ante desastres naturales en países en desarrollo, siempre que estén adaptadas al contexto local, basadas en la comunidad y enfocadas en la sostenibilidad a largo plazo.*

Palabras clave: *resiliencia, cambio climático, ciudades inteligentes; sur global; RRD.*

INTRODUCTION

The term "Smart Cities" became popular in the early 2000's when the companies Cisco and IBM announced investments in projects to investigate the use of sensors and data analytics in city planning (McNeill, 2015). The term is a reference to cities which incorporate information and communication technologies (ICTs) into their management and planning in order to provide better services, like more efficient energy consumption, waste treatment and recycling, public transport and road infrastructure. In a recent new addition, other elements like agriculture and health were added to equation (Lacson *et al.*, 2023).

One of the most influential and referenced frameworks defines all the components of a smart city in: Smart Economy, Smart Environment, Smart Mobility, Smart Governance, Smart Living and Smart People (Chourabi *et al.*, 2012). However, Bateman and Kainde (2022) propose a slightly different set of dimensions including smart branding and smart society instead of mobility and people. Additionally, a bibliographical review analyzed 98 definitions of smart cities and clustered them in 8 domains of a smart city, which turned out to be the following: (i) ICT, communication, intelligence and information; (ii) Governance, management and administration; (iii) Quality of life and lifestyle; (iv) Infrastructure and services; (v) People, citizens and society; (vi) Environment and sustainability; (vii) Economy and financial; and (viii) Mobility (ITU, 2014). There is not a special topic for Disaster Risk Management in most of them, just the broader topic "environment".

Some authors argue that for the cities which are at risk of catastrophes, it is an opportunity to think of smart disaster management (Lacson *et al.*, 2023). The importance varies from city to city, as natural catastrophes will depend on their context. Also, the less developed a country is, the starker can be the consequences of disasters. From 1970 until 2019, 91% of all deaths related to natural disasters, weather and climate hazards happened in developing countries (WMO, 2021).

While developing economies have lesser capacity to respond to the climate crisis, they are facing the most population and urban increment. Rapid urbanization and population increment can aggravate the climate emergency in developing countries if adequate disaster risk management strategies are not adopted in their urban areas. The share of people living in developing countries increased from 66% in 1950 to 83% in 2022 (UNCTAD, 2022). In 2016, 54% of the world's population lived in cities, a proportion projected to increase to 66% by 2050 (UNCTAD, 2017). Those figures show the importance of the intersection between smart cities and urban resilience in developing countries.

Climate change may manifest itself in many ways and these events not only affect livelihoods and cause economic losses. Nowadays, the world is already facing waves of climate refugees and cases of climate motivated internally displaced people (Myers, 2002). Some researchers believe that this situation has been responsible for bringing political instability to some countries, like strengthening the rise of terrorist groups in the Sahel Region (UN Press, 2021). Ultimately, climate change is responsible, directly and indirectly, for the killing of people

(WHO, 2023), for hinders socioeconomic development (Chandy, 2023), and is affecting the whole world landscape, affecting in a harsher way the poor (Tol, 2024; Hanna *et al.*, 2016).

Lastly, Bansal *et al.* (2017) highlights the importance of Disaster Risk Management in the discussion of smart cities, including in the developing world. However, most smart city research focuses on developed countries and flagship solutions, while resilience is frequently overlooked. This paper investigates the interface between smart cities and urban resilience narrowing the scope to the global south – countries who have greater limitations on implementing those solutions but can benefit from them the most. This research aims to explore the potential benefits that smart cities solutions may contribute to climate change adaptation and how can developing countries take advantage of it.

METHODOLOGY

This research was based on a qualitative approach with comparative studies. Data collection involved a comprehensive review of existing literature, including academic journals, case reports and official documents from international development organizations, that served as the foundations to compile findings and draw conclusions. Systematic literature reviews were prioritized as they infer from extensive analyses. Moreover, case studies were also analyzed as they anchor the discussion to real life examples and provide practical insights. English was the preferred language during the investigation, despite some case studies having primary sources in those country's native languages.

This paper is divided into four other sections: 1. "Urban Resilience in Developing Countries" gives a quick overview of the topic by laying out some concepts necessary to understand natural disasters in the global south; 2. "Smart City Technologies for Disaster Preparedness" adds smart cities to the equation by analyzing how they can be incorporated into the topics of the previous section; 3. "Case Studies and Outcomes" shows real-life examples of when smart cities initiatives were successfully implemented in developing countries and mitigated natural hazards impacts; 4. "Conclusion and final thoughts" wraps up the paper with a short summary of its content, key findings, limitations of the research and possible future steps.

URBAN RESILIENCE IN DEVELOPING COUNTRIES

THE CONCEPT OF URBAN RESILIENCE

Urban resilience is an essential focus in the study of cities and their ability to cope with and adapt to disruptions. It occurs in three ways: preparedness, responsiveness and recovery (Tonmoy *et al.*, 2020).

1. Preparedness refers to how the city – public administration, Civil Society Organizations (CSOs), grassroots organization, citizens and other stakeholders - prepares itself to reduce potential impacts from environmental hazards.
2. Responsiveness refers to how the city responds during and right after shocks.
3. Recovery refers to the ability to properly manage the recovery after natural disasters.

Agricultural and biological sciences, environmental engineering, business management and social sciences all have nuances in their definitions of urban resilience. In a literature review, Ribeiro and Pena Jardim Gonçalves (2019) defined urban resilience, as the

> "capacity of a city and its urban systems (social, economic, natural, human, technical, physical) to absorb the first damage, to reduce the impacts (changes, tensions, destruction or uncertainty) from a disturbance (shock, natural disaster, changing weather, disasters, crises or disruptive events), to adapt to change and to systems that limit current or future adaptive capacity" (Ribeiro *et al.*, 2019 p. 4).

Taghizadeh *et al.* (2015) presented a concept of the five dimensions of urban resilience: physical, natural, economic, institutional and social. Through these dimensions it is possible to characterize and evaluate cities' resilience. The authors also affirm that disaster indicators can be more relevant from one community to another, so when assessing urban resilience, they should be chosen and weighted accordingly (Taghizadeh *et al.*, 2015).

FACTORS SHAPING DISASTER PREPAREDNESS STRATEGIES IN DEVELOPING COUNTRIES

Natural disasters can occur in many ways, like floods, droughts, earthquakes, volcanic eruptions, cyclones, and landslides. These disasters posing a threat to economies and lives throughout the world. Developing countries, in contrast to developed ones, have fever resources and technical capacities to prepare, respond and properly manage recovery (Zorn, 2018). In addition, they are not a cohesive group: there are the Least Developed Countries (LDCs), the Small Island Developing States (SIDS); Heavily Indebted Poor Countries (HIPCs), Landlocked Developing Countries (LLDCs); these categories range from lower income to upper middle income (UN/DESA, 2014). Each of these groups has different needs, challenges and risks at stake. They are also not mutually exclusive, and some countries may appear on more than one list.

Small developing island states don't face all the same challenges that landlocked developing countries, upper middle income will have different disaster risk management capabilities of heavily indebted countries, and so on. However, to a certain degree, all developing countries face poorer institutions, lower technical capacities, pre-existing structural issues and fewer financial means to address natural disasters compared to developed countries.

The natural hazards impact depends on many different factors, like the country's **income**, **institutions**, **education and customs.** In January 2010 a 7.0-magnitude earthquake hit Haiti, killing 200,000 people. In February 2010, an 8.8-magnitude earthquake hit Chile, killing approximately 500 people (Pallardy *et al.*, 2024), despite being 500 times stronger than Haiti's shock[1] (Wayman, 2012). Chile strong building code was said to be the defining factor in that episode. Chile too learned from previous events: most of the casualties of an earthquake in 2010 happened due to a tsunami caused by it and when an 8.2-magnitude earthquake happened in 2014, they were able to evacuate 1 million people from tsunami-prone areas and avoid a bigger catastrophe (CFM-DM, 2017). The 2014's case is just another example of how strong institutions play a big role in Disaster Risk Reduction (DRR).

Within one country, region or city, **socio-economic disparities** also manifest in disasters management (SAMHSA, 2017), as richer families and communities have more capacity to buy insurance, stockpile supplies, investment and recovery capacity and better infrastructure.

Another driver is **rapid and unplanned urbanization**. Developing countries are rapidly increasing urban population without providing basic services and adequate infrastructure for the new dwellers. These conditions are catalysts for natural hazards becoming humanitarian disasters. As these cities face a strong **population growth,** existing infrastructure may be overburden, natural ecosystems may be destroyed and the sole action of managing risk becomes more complex (UNDRR, 2013).

Infrastructure quality is also important as sometimes, due to lack of tenure security, poorer populations avoid investing in costlier but durable housing solutions. Building regulations can be too strict and not attainable, or too weak and permit vulnerable constructions (Hallegatte *et al.*, 2016). If resilient, water, transport and electricity infrastructures can provide services right after a disaster and relief its outcomes. If not, they might hinder the recovery efforts and even cause more damage (UNDRR, 2013).

Climate change is also paramount to the disaster management discussion. Although natural disasters have been present throughout human history, there is substantial evidence that the current trend of average world temperature rise is human-induced and is causing extreme events to be more common (López *et al.*, 2018).

International organizations act on advocacy and providing support, technical or financial, playing a role of bringing light to disaster risk management and implementing projects which will avoid losses of lives, infrastructures, livelihoods and investments. Institutions like CSOs, universities, NGOs, development banks, community associations, private sector and other stakeholders can also be relevant actors in preparedness strategies(Shaw, Izumi, 2015; Izumi, Shaw, 2014; Gibson, Wisner, 2019) .

Climate governance, policies and frameworks affect how communities and public administration plan and respond to disasters. National strategies and established protocols, for instance, serve as a guide for local level authorities better manage risk (UNDRR, s.d.).

Geographical characteristics of each country are also determinant on how the preparedness strategies are planned. Small island developing states are usually more vulnerable to cyclones and sea level rises (Shultz et al., 2016), while having economies heavily reliant on one or two sectors (tourism in most cases); whereas landlocked developing countries are more vulnerable to external shocks compared to their coastal counterparts and rely on others to export their productions to the global market and to access goods and services (Faye *et al.*, 2004).

Finally, **cultural background** is determinant to disaster preparedness, as it influences how communities and their leaders act on this matter. Collective memory, popular knowledge, exclusion of minoritarian groups, values and gender roles are just some of the cultural elements which affect disaster management (Appleby-Arnold *et al.*, 2021). In this sense, inclusive awareness raising and education can impact on how these communities deal with disaster risk.

SENDAI FRAMEWORK AND THE CURRENT STATE OF URBAN RESILIENCE IN THE GLOBAL SOUTH

The current trend of urban resilience is alarming: 84% of the world's fastest growing cities are rated as 'extreme risk' and other 14% are 'high risk' (Verisk Maplecroft, 2018), most of them in Asia and Africa. Different countries have approached urban resilience either at national level or sub-national, depending on how informed and capable those public administrations are. As mentioned in the previous topic, international organizations have played a role in advocacy and providing support to those countries in their disaster risk management. Here are some explanations of international initiatives to coordinate risk response:

The **Sendai Framework for Disaster Risk Reduction** (SFDRR) is an international agreement aimed at reducing natural disasters losses in terms of lives, livelihoods, economy, health, etc. (UN, 2015). It was the major agreement signed after the establishment of the 2030 Agenda and has 187 member states adopting it. The framework outlines seven global targets and four priority actions for addressing natural disasters, to be implemented from 2015 to 2030.

In the 8th anniversary of the SFDRR, which means a middle point between its signature and implementation end date, the United Nations Office for Disaster Risk Reduction (UNDRR) produced a midterm report (MTR-SF) using data from the 75 member states who submitted their voluntary national reports (UN, 2023). The midterm review acknowledges that developing countries have made progress in understanding and managing disaster risks in the past 8 years, but many challenges remain.

The groups of least developed countries, landlocked developing countries and small island developing states acted poorly compared to other developing countries (UN, 2023). This is not by chance, since least developed countries suffer from problems with political instability, lack of funds, lack of technical capacity and poor institutions, while SIDSs and LLDCs have their particular geographical limitations.

Many developing countries were identified as lacking adequate data collection and analysis on disasters, economic losses and risks. Also, disaggregation of data was poor in many cases, with no distinction by age, gender or sub-national levels (UN, 2023). Poor quality in data collection is reflected in poor diagnostics and risk management.

Disaster risk reduction plans in developing countries also lacked community and political engagement when compared to developed countries, with many of them disregarding the potentials of a good intersectoral cooperation between governmental agencies, public institutions, international actors, civil society and others, like marginalized groups and local communities (UN, 2023).

The midterm review of the Sendai Framework calls for a shift in the approach to disaster risk reduction, from managing disasters to managing risks (UN, 2015). In essence, to focus more on preparedness rather than waiting for hazards to occur and then responding and recovering. Strengthening cooperation South-South is also stressed as an opportunity to increase climate resilience and knowledge sharing.

Within the contexts of the Midterm Review of the Sendai Framework, but focused on urban resilience, UNDRR prepared a report after conducting interviews with local authorities and urban practitioners, to understand how the Sendai Framework was implemented at city level, its challenges, lessons learned and achievements (UNDRR, 2023). Some of the outcomes were: the most success was in increasing risk awareness and institutionalization of disaster risk management in public. Also, greater focus should be placed on small and medium-sized cities and financing for disaster risk reduction and de-risking investments[2]. Finally, the areas which require more attention were said to be water (e.g. sanitation, provision and wastewater), social inequalities and food security (UNDRR, 2023).

There are other meaningful movements from the international community aimed at increasing resilience in the urban environment. For example, the **Resilient Cities Network** connects chief resilience officers, researchers and practitioners of 100 cities globally to support resilience projects and exchange expertise. Funded by the Rockefeller Foundation, this network is not focused on countries of the global south, but roughly 50% of the selected cities are from them. Just in the last two years, it has supported 52 urban resilience projects (Resilient Cities Network, 2023).

The **Cities Resilience Program** (CRP) is another important initiative. Launched in 2017, managed by the Global Facility for Disaster Reduction and Recovery (GFDRR) and implemented by the World Bank, it aims at increasing financing for urban resilience. It provides technical and financial support focusing on three areas: planning for resilience, finance for resilience and partnership for resilience. The CRP has implemented projects in 140 cities throughout 66 countries. Among its projects, flood risk investments in Bamako (Mali) (Pilkington, 2023), a heat watch system in Bosnia & Herzegovina (CAPA Strategies, 2023) and coastal resilience in Gambia (World Bank, 2022). Other areas of intervention are advocacy and development of frameworks, tools and publications.

Finally, it is worth mentioning the **Making Cities Resilient 2030,** a multi-partner initiative, which include the World Bank, various UN-Agencies, different city networks and other humanitarian players, like the Japanese International Cooperation Agency and the Red Cross and Red Crescent Society. It works in awareness raising, capacity building, city-to-city learning, technical support both at global and regional level (MCR2030, s.d.). As one of their outcomes, more than 4,350 cities signed a MCR campaign on disaster risk awareness in their first campaign. Nowadays, they advocate for the resilience roadmap of cities knowing, planning and implementing better risk reduction and resilience actions.

SMART CITY TECHNOLOGIES FOR DISASTER PREPAREDNESS

INFORMATION AND COMMUNICATION TECHNOLOGIES APPLIED TO NATURAL DISASTERS

Smart City Technologies offer immense potential for the identification, monitoring and management of disaster risk. Through the use of advanced data analytics, real-time monitoring and integrated systems, these technologies enable cities to predict, prepare for and respond effectively to various hazards, thus enhancing urban resilience and safety (DesRoches *et al.*, 2018). Additionally, smart city solutions can contribute to long-term sustainability goals and environmental preservation by optimizing resources use and reduce waste. As a result, the topic of smart cities and climate change adaptation has gained significant attention in recent years as cities seek to build resilience and sustainability.

Researchers from different fields have explored various aspects of smart city development and their impact on climate change adaptation, leading to a range of methods of reading and classifying smart cities. In this context, Huang-Lachmann's (2019) arranged solutions according to 6 dimensions: smart economy, people, governance, mobility, environment, and living – the same classification used by Chourabi *et al.* (2012).

These 6 dimensions have non-linear relationships among them. Three of them are foundations which the others depend on to achieve greater results in the realm of smart city and climate change adaptation (Huang-Lachmann, 2019). The author mentions that the most relevant dimensions are **smart governance** (public sector), **smart people** (general public) and **smart environment**. This way, the author claims, there can be synergies which produce co-benefits throughout many other sectors thanks to stakeholders' engagement. By focusing on smart governance, people and environment, stakeholders' engagement is enabled to continue after involvement level, allowing co-production, co-design, co-development and co-creation. As consequence, these result in better public ownership, awareness, capacity building and engagement (Huang-Lachmann, 2019).

Huang-Lachmann's statement goes hand-in-hand with what the report of Woetzel *et al*. (2018) claims as good smart cities solutions: "they should start with people, not technology". It's not about using flagship sensors and cameras, but using data and technology to make better and inclusive decisions.

Finally, Huang-Lachmann (2019) compiles many of smart city initiatives, according to their dimension. Some of those related to urban resilience are presented below:

- **Smart economy:** Integrated modelling for crops yield; GIS for analyzing heat exposure; meteorological model for health impact calculations; and remote sensing for assessments (e.g. flooding risk, sea level rise) (Huang-Lachmann, 2019).
- **Smart people and smart governance:** Promoting climate literacy among residents and decision makers, integration of local stakeholders into the planning process; and bottom-up or decentralized initiatives (Huang-Lachmann, 2019).
- **Smart mobility and smart living:** Context-based resilient housing design; vulnerable housing and infrastructure regulations; sustainable and secure food supply; nature-based solutions for climate smart housing; and public space with multi-purpose design (Huang-Lachmann, 2019).
- **Smart environment:** Smart grid; investments in local water sources (recycled water and shallow groundwater); and solar panel for cooling effects (Huang-Lachmann, 2019).

TAILORING SMART CITY SOLUTION TO DEVELOPING COUNTRIES

The theme "Smart Cities" is transversal to many fields of knowledge, like computer science, urban planning, energy, public policy, social science and engineering. A bibliographic review of smart city journals from Lacson *et al*. (2023) found that among all those disciplines, articles related to smart cities in developing countries focused mostly on "sustainability and the environment" or "energy". These two topics are related to climate change response, but mainly to mitigation.

Climate change response is divided in two: mitigation and adaptation. Climate change mitigation focuses on reducing the root causes of climate change (e.g. lowering greenhouse gases emissions, consumption, carbon sequestration), while climate change adaptation aims at reducing its impacts on human lives, infrastructures, livelihoods and natural systems (e.g. drought resistant infrastructure, flood defenses, early warning system) (WWF, s.d.). These two categories sometimes can be contradictory. For instance, Miami city used millions of federal American Rescue Plan dollars to buy air conditioners to social housing units to prevent deaths due to extreme heat waves: a solution which adapts the built environment to climate change, while at the same time contributes to high energy consumption and carbon emissions (Kempe, 2023). However, adaptation and mitigation are not necessarily in opposition and should be thought as complementary strategies (UCLG ASPAC, 2024). For example, protecting waterfront vegetation acts as preventing erosion and coastal flooding, while sequestrating carbon.

In this paper, climate change adaptation is mainstreamed over mitigation. It focuses first on addressing the impacts of the intensification of natural disasters on the most vulnerable people, acknowledging at the same time the principle of 'common but differentiated responsibilities'[3] (UNFCCC, 1992). Including smart city technologies in disaster resilience has a potential to improve risk management throughout its whole chain: **preparedness**, **responsiveness** and **recovery**. At the same time, not all solutions that have been successful in some developed countries could be easily applied in others, especially in the global south.

As for the possibilities of improving preparedness, the use of information and communication technologies facilitates the public administration to make risk informed and data driven decisions (Kő *et al.*, 2015). For instance, the city of Philadelphia used ICT for environmental management when, by modelling water runoff and planning a network of green roofs, wetlands and other green infrastructures, avoided overwhelming the city's sewage system during storms (Stutz, 2018).

The way the city responds to natural hazards can be enhanced through the use of early warning systems, rapid assessment after shock and better aid delivery. For example, Mozambique - a country that has suffered frequently from tropical cyclones - demonstrated responsiveness when Cyclone Freddy hit its coast in 2023. The Institute of Social Communication alerted 70 communities through radio and trained brigades, resulting in minimal human losses despite significant infrastructure damage (World Bank, 2023). Similarly, after the Guerrero-Oaxaca earthquake hit Mexico in 2012, the company *Telefónica* used anonymous mobile data to trace mobility patterns to help delivering aid to the locations where people relocated after the disaster rather than where they were before, while giving a real time tool to assess the response efforts (Frías-Martinez, 2016).

Finally, informational and communication technology can improve recovery efforts for a long-lasting resilience (Samarakkody *et al.*, 2023). Initiatives like "build-back-better" can benefit from data insights like direction where to direct city growth and which infrastructures and neighborhoods to receive determined improvements (DesRoches *et al.*, 2018). Community can be engaged in different steps its recovery like producing, designing and creating solutions which are not only better, but create ownership among citizens and serve as awareness raising.

These solutions are not always easily replicable in all contexts. The first limitation the comes to mind is the lack of adequate infrastructure: many of the flagship practices of smart cities require top notch infrastructure like fast internet connections and high-end sensors; as developing countries not always have these technologies available, there is a need to adapt solutions to their own context (Ahada *et al.*, 2020).

Sustainability of initiatives may be complicated in some cases as maintenance of practices depends a lot on political will, institutional stability and financial capability. This challenge gets another layer as it depends on coordination among national and sub-national governments departments. These sub-national administrations suffer from the same problem mentioned above, but in a greater way, with less technical capacity, money and autonomy (Leck *et al.*, 2013).

Some other hindering conditions have been observed in other cases. Digital literacy and public awareness can be a limitation in data collection and community buy-in. In fact, community's interest can be a problem in countries where there are weak institutions or disaffection with their political representation at local level (Swapan, 2016). Weak institutions also raise concerns in regard to data privacy and this may hinder political participation (Cilliers *et al.*, 2015).

Finally, environmental sustainability issues may appear, since some decisions may increase energy consumption and generate electronic waste, causing more bad than good – like poor air quality and increase CO^2 emissions.

CASE STUDIES AND OUTCOMES

Bibliographic review shows us different approaches to disaster risk management in different developing countries, each with their own particularities and contexts. The following three case studies were selected with this diversity in mind and to illustrate how smart cities solutions can improve urban resilience in the global south. They illustrate the three steps of disaster risk management: **preparedness**, **response** and **recovery**, and differentiate in their geography: South America, Southeast Asia and Sub-Saharan Africa.

STUDY CASE #1 – PREPAREDNESS: "ALERTA RIO", RIO DE JANEIRO CITY'S EARLY WARNING SYSTEM (EWS) FOR HEAVY RAIN

Due to its geographical characteristics and historical background, the city of Rio de Janeiro (Brazil) has suffered with floodings and landslides for centuries. Home to almost 7 million people, the second biggest Brazilian city has 22% of its population living in slums (Miyamoto *et al.*, 2022). These informal settlements are usually densely occupied and located on mountains and river valleys, while lacking adequate services and infrastructure. The sum of all these factors reflects a landscape highly vulnerable to natural hazards – which ultimately results in deaths and heavy economic losses for the poorest populations of the city.

Figure1: Map of Rio de Janeiro. Created by the author. Data from OpenStreetMaps and Mapzen Global Terrain

The first pilot program for early warning systems in Rio de Janeiro was the SIGRA – Geotechnic Instrumentation System via Radio – in the 1980's (Piciullo *et al*., 2015). The current system in Rio de Janeiro – *Alerta Rio* – started to be implemented as an early alarm system in 1997 (Hanna, 2019). It kickstarted one year after a series of heavy rains hit the city in 1996, leaving nearly 250 people dead and 50,000 people displaced. The next year, there were another 300 casualties in a similar event (O Globo, 2010). The "A2C2" system has been through some upgrades, like the first in 1999 – when they included Doppler radar and their own geo-technical foundation – and the most impactful in 2010 – which is the object of study of this subsection.

During the 2010 update, 117 communities were assessed and given a score of low, medium or high-risk. These places were categorized by characteristics as slope, soil profile and previous disasters. However, this early warning system is considered a success not only because of informing people when there is a risk (Heffe, 2013). This initiative used the national public service to (1) map all those people with disabilities who would need support to evacuate the area in case of emergency, and (2) make the health assistants – who visit those communities once a month and are well perceived by the households - raise awareness of the local population about natural hazards and the alarm system (Heffe, 2013). Other means of awareness raising were public campaigns, flyers, free T-shirts and incorporation of disaster response in classes for kids in middle school. In addition, evacuation simulations help to educate the locals and community leader's support tend to those initiatives.

In 2010, when the upgrade happened, *Alerta Rio* had 117 pluviometers, 116 sirens and the radar system mentioned before. Besides that, the operation center had more than 1,000 cameras for monitoring live footage from the city and had technology to issue SMS messages to trained community leaders and dwellers. Rio's Early Warning System is considered a successful case and the average of casualties from floodings and landslides have decided dramatically – as of Heffe's publication (2013), not one death had been recorded since the upgrade and many evacuations during adverse conditions had successfully been made.

However, there is room for improvement in *Alerta Rio*. In 2019, seventeen people lost their lives due to two major rainfalls - what sparked questioning and discussion on the EWS. In one of these two events, the sirens did not ring because the rain was not strong enough for the protocol (Folha de S. Paulo, 2019). In many other occasions, there have been false alarms (Calvello *et al.*, 2013). Abby (2019) proposes the incorporation of (or substitution to) the "Slope ALARMS" system, which predicts a landslide not based on rainfall, but on the acoustic emissions generated by soil grains moving before a landslide. This system, she claims, tends to be more accurate, uses cheaper sensors, can be automatized and would generate less false alarms.

Another problem is related to governance, as the system depends on the city's administration and is vulnerable to the mayor's political will and municipal budget. After one event which took 7 lives, one newspaper found out that Rio's mayor had cut flooding prevention budget by 71% during his term (Folha de S. Paulo, 2019).

Still in the realm of governance, some people are afraid of leaving their homes during natural disasters because they fear not being able to go back or losing their belongings. In this sense, securing land tenure can help to avoid human losses, at least of those who fear having their home taken by the state due to lack of deed.

Finally, it is also important to bear in mind that this system needs adaptations to be replicated in other locations. Although Brazil is a developing country, Rio is the capital of one of the richest states and it's GDP per capita is around $10,000 – which is way above national average and most developing countries, somewhat close to the $12,615 threshold the United Nations consider as a minimum for being considered a high-income country (UN DESA, 2021).

Figure 2: Rio's Early Alarm System Operation Center. Source: The World Bank

STUDY CASE #2 – RESPONSE: "PETA BANCANA", CROWDSOURCING FOR URBAN RESILIENCE IN INDONESIA.

Similar to Rio de Janeiro, Jakarta (Indonesia) has a combination of geographical conditions and historical background which result in a large amount of its population vulnerable to disasters. Jakartans suffer from poor infrastructure (especially in terms of drainage), unorganized urban growth, poor waste management, lack of adequate services and funds for disaster risk management. Moreover, the city lies on top of a geologically vulnerable ground and is literally sinking (Renaldi, 2022), increasing its sea-level rise vulnerability. Due to these threats, there is a new Indonesian capital city being built on higher and more stable site.

The result of all the conditions generate a city which consistently suffers from floods – 72% of its area is vulnerable to it (Holderness *et al.*, 2015) – but also is frequently hit by landslides, tornadoes and earthquakes[4] (Firman *et al.*, 2011). Given that the climate crisis tends to inflict increasingly extreme events, climate change adaptation strategies like Peta Bencana are necessary in such contexts.

Figure 3: Map of Jakarta. Created by the author. Data from OpenStreetMaps and Mapzen Global Terrain

Initially named as PetaJarakta.org, *Peta Bencana* is a crowdsourcing, volunteered geographic information (VGI) system developed by the University of Wollongong (Australia), the DKI Jakarta Regional Disaster Management Agency and Twitter Inc (Ogie *et al.*, 2018).

Initially piloted in 2013 and only applied to Indonesia's capital city, Peta Jakarta was later expanded and turned into *Peta Bencana* – including the cities of Jabodetabek (greater Jakarta), Surabaya, and Bandung (Peta Bencana, s.d.). It works by gathering live data from social media users who are mentioning floods – including GPS location, text description, how deep is the flood (e.g. it the water is reaching knee height or neck's), photos and videos – which are sent to control rooms, processed and turned into live maps of the situation. With that data, the public authority addresses aid and response teams according to the locations, number of occurrences and intensity of need. At the same time, since all the data is public, any citizen can use the platform to safely navigate through the city during these events.

More than a decade after its initial steps, the platform is widely adopted. In the past, flood maps had to be manually made and would take up to 6 hours to be made, compared to the real-time maps of *Peta Bencana* (Song *et al.*, 2020). Besides the expansion to other cities, the system also received other improvements, in 2015 two other online platforms were integrated: *Qlue*, which allows other problems to be mapped (e.g. theft, traffic) with lengthier texts than Twitter; and *PasangMata*, which allows users to act as reporters in a news website. Recent additions included new categories – such as extreme winds, volcanoes, forest fires, hazes and earthquakes – and links to Telegram and Facebook (Peta Bencana, s.d.).

However, *Peta Bencana* also has its flaws. In general, crowdsourcing and volunteered geographic information can gather poor quality data – e.g. lack of accuracy, redundancy, bad intentioned users (Goodchild *et al.*, 2010). Problem which is solved when the control room analyzes, evaluates and cross-validates data from users, helping to give more objectivity to thousands of subjective inputs. This is aligned to what Huang-Lachmann (2019) mentions as good example of synergy between smart governance, environment and people, resulting in a co-production[5] of flood maps. Some other concerns raised can be a threat in the future. Researchers did not find a long-term financial strategy as it relies mostly on donations (Song *et al.*, 2020), but nowadays, four years after the article, Peta Bencana is still functioning. Another vulnerability is the over reliance on a specific social media – a problem which is losing its importance as more platforms are being added to the basket of the service. One chance for improvement would be researching the profile of those users. Incentives should be placed to make people of different genders, age groups and incomes participate and make it more democratic and representative.

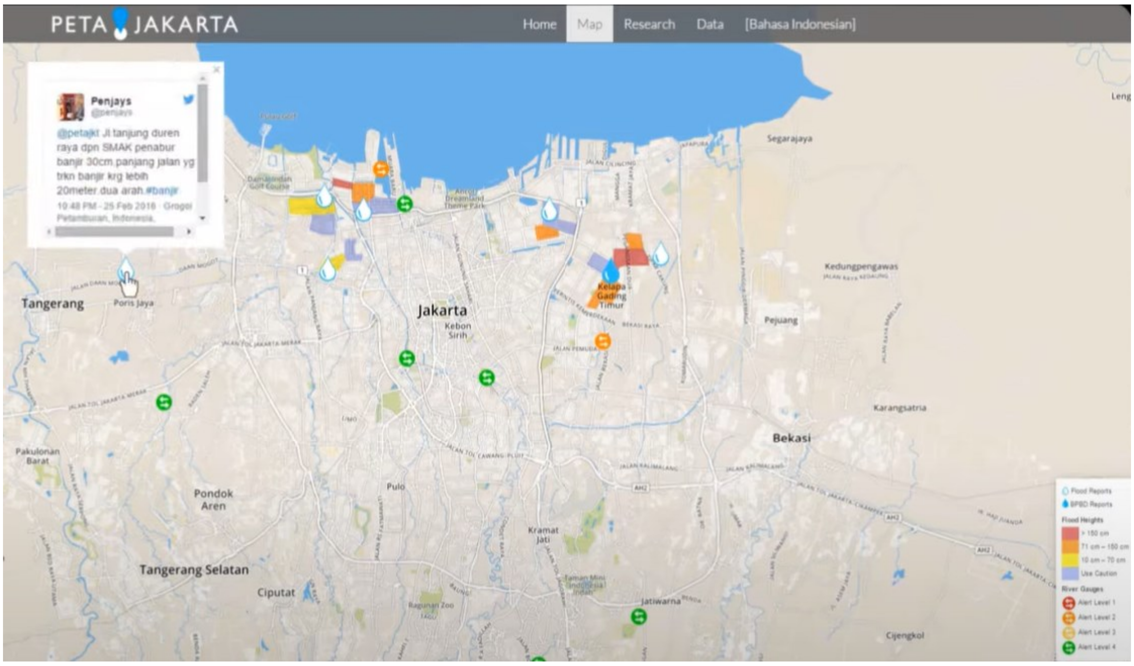

Figure 4: Example of live flood map from *Peta Bencana*. Source: Peta Jakarta website

Despite some points of concern, *Peta Bencana* is successful as it has grown and got more elaborate throughout its first decade of existence. It explores the potential of crowdsourcing, increases the speed and ability to adapt, to coordinate and to make decisions based on evidence. Moreover, *Peta Bencana*'s experience can be replicated thanks to the open-source software. Through this system, the city has been able to self-organize and the information is not transmitted in a top-down or bottom-up manner, but both ways; not in a one-to-one or one-to-many fashion, but rather from many-to-many users (Song *et al.*, 2020).

STUDY CASE #3 – RECOVERY: "FREETOWN THE TREETOWN", REFORESTATION INITIATIVE IN SIERRA LEONE'S CAPITAL

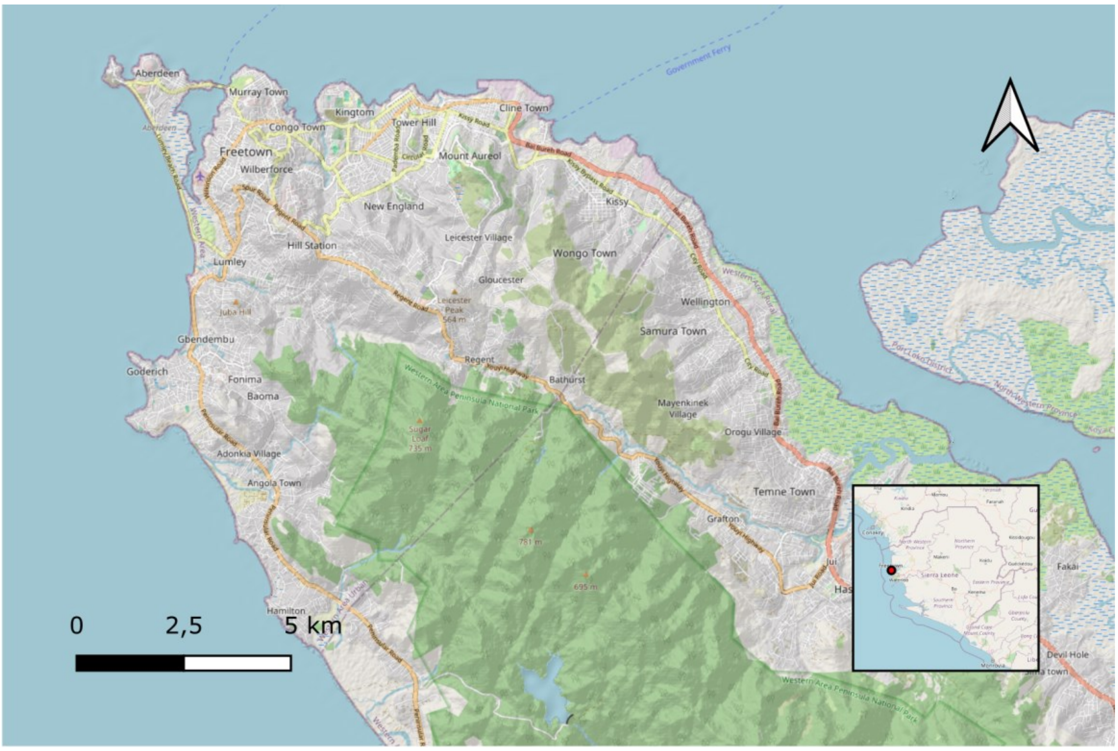

Figure 5: Map of Freetown. Created by the author. Data from OpenStreetMaps and Mapzen Global Terrain Created by the author.

Sierra Leone is one of the most vulnerable countries to climate change (Ahonsi, 2022). Its capital Freetown is located by the Atlantic Ocean and suffers a lot from floods, landslides, coastal erosion and heat islands[6]. All these problems are connected and have been intensified as the country is rapidly urbanizing: Freetown lost on average, 12% of all canopies in the city each year from 2011 to 2018, while receiving roughly 100,000 new inhabitants yearly (Fisseha *et al.*, 2021).

Freetown City Council and Western Area Rural District Council partnered up with the nonprofit called Greenstand and kickstarted the "Freetown the Treetown" campaign (C40 Knowledge Hub, s.d.) an initiative to increase the city's canopy coverage by 50% (compared to 2018 numbers) through planting 1 million trees in the most vulnerable places from 2020 to 2023.

By planting trees in strategic spaces, it is expected that all four natural hazards mentioned in the previous paragraph to be weakened, especially urban heat islands.

Any citizen is free to sign up via smartphone and is paid to plant trees using an open-source app called TreeTracker. The growers register themselves through their smartphones, plant a tree, take a photo, assign an ID and geotagged record of it. They are in charge of watering and maintaining their planted trees, which are virtually checked once a quarter. The grower takes pictures of each tree and gets mobile micropayment for maintaining them. Payment occurs every two months for the first three to five years of the plant's life (C40 Knowledge Hub, s.d.).

According to Eric Hubbard (2023), senior advisor to the Mayor of Freetown, today there are around 1,200 community growers across the city (responsible for approximately 1,000 trees each), 80% who are youths and 48% women (C40 Knowledge Hub, s.d.). Growers who get to have income for planting and protecting forestry in their own community, $1 per tree on average.

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"Freetown the Treetown" created a climate market which can help this initiative to be self-sustaining in the long term (Barrass, 2024): any planted tree is a token which can be traded – transferring its duties to a new user, who in exchange will collect that tree's micropayments for maintaining it. The project was initially funded by the World Bank ($1.8 million) and got another capital contribution ($1 million) from the Bloomberg Global Challenge. Lont-time sustainability, however, does not count on those donors: tokens offer impact investment opportunities and are currently being traded through corporate social responsibility (CRS) contracts. Today they are already responsible for 25% of the project's revenue (C40 Knowledge Hub, s.d.).

The program was such a success that the initial figure of one million trees – from 50 different species (Barrass, 2024) – was reached before the initial deadline and the observed tree survival rate is above 80% (Fisseha *et al.*, 2023). The program was expanded and now five million trees are expected to be planted by 2030 and 20 million by 2050.

"Freetown the Treetown" is an example of how a climate change adaptation strategy can also be a climate change mitigation strategy. At the same time, it is an impactful and replicable nature-based solution. Afforestation fights urban heat islands by lowering temperatures in urban areas, prevents coastal erosion by recovering native mangroves that protect the coast from storm surges, keeps Freetonians from harm caused by floods when increases soil absorption and slows water runoff, and improves soil stability in slope areas, which ultimately prevents landslides like the one in 2017 which killed more than 1,000 people (Ratcliffe, 2017).

Figure 6: Tree certification via smartphone. Source: C40 Knowledge Hub

CONCLUSION AND FINAL THOUGHTS

This paper explored the interface between smart city technologies and urban resilience in developing countries, with special attention to disaster risk management. Through different sources – literature reviews, academic articles, reports and manuals from international organizations and case studies – the research shows the importance and potential of incorporating information and communications technologies for enhancing disaster preparedness, response and recovery in cities of the developing world.

Developing countries, however, were proven to have their own limitations in deploying many of the top tier smart cities initiatives the developed world has successfully implemented. Although some researchers have found that smart city concepts are criticized and discarded by authorities in the global south for being deemed as expensive and ill-suited to local realities (Anandira, 2023), this research showed that when those limitations are addressed and adapted to the local context, new possibilities to tackle present and future climatic challenges emerge.

The case studies of Rio de Janeiro's Early Warning System, Jakarta's crowdsourcing platform Peta Bencana and Freetown's reforestation initiative have provided empirical support for this claim. Each of them is successful implemented technologies adapted to their national and sub-national context. They have also demonstrated the potential of smart cities to transform urban disaster management by fostering community engagement, enhancing real-time data analysis and promoting sustainable environmental practices.

The research has identified several key findings:

- Urban resilience manifests through preparedness, responsiveness and recovery, with smart city technologies playing a crucial role in each phase.
- The application of information and communication technologies in disaster risk management can lead to more informed decision-making and efficient resource allocation.
- Community-based initiatives, supported by smart technologies, can improve the resilience of urban areas to disasters as they enable inputs and collaboration in different steps of the process.

This research also has its limitations. The case studies picked are successful but they are just a limited sample to make stronger general assumptions. Future research should aim to broaden the scope of case studies to include a wider range of urban contexts and disaster types. It could also dive into case studies and analyze other spheres of the outcomes, like their economic and social impacts. Also, despite all challenges mentioned in deploying smart cities solutions to developing countries, there is a large number of organizations, funds and other partners which can provide technical assistance, exchange of expertise and funding – being this another research path which could be delved.

In conclusion, this paper has highlighted the transformative potential of smart city solutions in enhancing urban resilience in developing countries. Lessons learned from this research will become ever more critical as climate change progresses. It is hoped that insights provided can contribute to the development of more resilient urban environments in developing countries, helping them to face natural disasters' challenges from today and tomorrow.

REFERENCES

AHADA, Mohd Abdul; PAIVA, Sara; TRIPATHI, Gautami; FEROZ, Noushaba. "Enabling technologies and sustainable smart cities". **Sustainable Cities and Society**, 2020.

AHONSI, Babatunde. "Why COP27 matters to Sierra Leone". **Renewal Africa**, 2022. Available at: https://www.un.org/africarenewal/magazine/november-2022/why-cop27-matters-sierra-leone.

ANANDIRA, Hana. **Blog: Can there be smart cities in developing countries?** Mobile World Live, 2023. Available at: https://www.mobileworldlive.com/blog/blog-can-there-be-smart-cities-in-developing-countries%E2%80%AF/.

APPLEBY-ARNOLD, Sandra; BROCKDORFF, Noellie; JAKOVLJEV, Ivana; ZDRAVKOVIĆ, Sunčica. "Disaster preparedness and cultural factors: a comparative study in Romania and Malta". **Disasters**. 2021.

BANSAL, Neha; GAIROLA, Ajay; MUKHERJEE, Mahua. **Smart Cities and Disaster Resilience.** 2017. pp. 109-122.

BARRASS Karen. **Building low-carbon resilience into Freetown's future**. International Institute for Environment and Development, 2024.

BATEMETAN, Q.C.; KAINDE, J.R. “Understanding Smart City Strategy In Developing Countries’ Cities”**. Theoretical and Empirical Researches in Urban Management**, 2022.
C40 Knowledge Hub. **Freetown’s highly replicable way of self-financing urban reforestation.**
CALVELLO, Michelle; NEIVA, D’orsi Ricardo; PICIULLO, Luca; NELSON, Paes; MAGALHAES, Marcelo; LACERDA, Willy A. “The Rio de Janeiro early warning system for rainfall-induced landslides: Analysis of performance for the years 2010–2013**”. International Journal of Disaster Risk Reduction**, 2013. Vol. 2.
CAPA Strategies. **Heat Watch Bosnia-Herzegovina** - Community Heat Mapping in Mostar and Sarajevo.2023.
CFM-DM. **Chile - Disaster Management Reference Handbook**. Center for Excellence in Disaster Management & Humanitarian Assistance, 2017.
CHANDY, Lawrence. **Economic Development in an Era of Climate Change**. Peace Carnegie Endowment for International, 2023.
CHOURABI, Hafedh; NAM, Taewoo; WALKER, Shawn; GIL-GARCIA, J. Ramon; MELLOULI, Sehl; NAHON, Karine; PARDO, Theresa A.; SCHOLL, Hans Jochen. **Understanding Smart Cities**: An Integrative Framework. 45th Hawaii International Conference on System Sciences, 2012.
CILLIERS, Liezel; FLOWERDAY, Stephen. “Information Privacy Concerns in a Participatory Crowdsourcing Smart City Project”. **International Journal of Internet Technology and Secured Transactions**, 2015. pp. 280-287.
DESROCHES, Reginald; TAYLOR, John E. “The Promise of Smart and Resilient Cities**”. The Bridge**, 2018. pp. 13-20.
FAYE, Michael L.; MCARTHUR, John W.; SACHS, Jeffrey D.; SNOW, Thomas. “The Challenges Facing Landlocked Developing Countries”. **Journal of Human Development**, 2004;
FIRMAN, Tommy; SURBAKTI, Indra M.; IDROES, Izhar Chaidir; SIMARMATA, Hendricus A. **Potential climate-change related vulnerabilities in Jakarta**: Challenges and current status. Habitat International, 2011.
FISSEHA, Tiguist; TOYA, Akiko; COWAN, Nuala Margaret; DUMA, Larissa. **#FreetownTheTreeTown campaign**: Using digital tools to encourage tree cultivation in cities. Blog | World Bank, 2021.
Folha de S. Paulo. **Gasto com prevenção a enchentes no Rio cai 71% sob gestão Crivella**. Folha de S. Paulo, 2019.
Folha de S. Paulo. **Sirenes não foram acionadas em morro onde duas pessoas morreram**. Folha de S. Paulo, 2019.
FRÍAS-MARTINEZ, Enrique. **How big mobile data can help manage natural disasters.** Telefonica, 2016. Available at: https://www.telefonica.com/en/communication-room/blog/how-big-mobile-data-can-help-manage-natural-disasters/.
GIBSON, Terry; WISNER, Benjamin. “Global Overview of the Role of Non-Governmental Organizations in Natural Hazard Governance**”. Natural Hazard Governance**. Oxford Research Encyclopedia of Natural Hazard Science, 2019.
GOODCHILD, Michael F.; GLENNON, J. Alan. “Crowdsourcing geographic information for disaster response: A research frontier”. **International Journal of Digital Earth**, 2010. pp. 231-241.
HALLEGATTE, Stephane; VOGT-SCHILB, Adrien Camille; BANGALORE, Mook; ROZENBERG, Julie. **Unbreakable:** building the resilience of the poor in the face of natural disasters. World Bank, 2016.

HANNA, Abby. **Rio's Landslide Mitigation Tactics, Part 2:** Potential Improvement Via Acoustic Emissions. Rio On Watch, 2019.
HANNA, R; PAULINA, Oliva. **Implications of Climate Change for Children in Developing Countries**. The Future of Children. Princeton University, 2016. Vol. 26. pp. 115-132.
HEFFE; Charlotte Olivia. **Rio de Janeiro city's early warning system for heavy rain**. Policy Brief - ELLA Area: Environmental Management. ELLA - Evidence and lessons from Latin America, 2013.
HOLDERNESS, T.; TURPIN E. . **PetaJakarta.org:** Assessing the Role of Social Media for Civic Co-Management During Monsoon Flooding in Jakarta, Indonesia. SMART Infrastructure Facility, University of Wollongong, GeoSocial Intelligence Working Group White Paper 01, 2015.
HUANG-LACHMANN, Jo-Ting. "Systematic review of smart cities and climate change adaptation. Sustainability Accounting", **Management and Policy Journal**. Emerald Publishing Limited, 2019. Vol. 10. pp. 745-772.
HUBBARD, Eric. **#FreetownTheTreeTown:** A Community-Driven Tree-Planting Revolution. Creative Bureaucracy Festival, 2023.
ITU. **Smart sustainable cities** — Analysis of definitions. International Telecommunication Union - Focus Group on Smart and Sustainable Cities, 2014.
IZUMI, Tanako; SHAW, Rajib. "Role of Civil Society Organizations in Policy and Advocacy in Risk Reduction"**. Disaster Risk Reduction**, 2014. pp. 15-27.
KEMPE, Isabelle. **Fight or adapt to climate change? It's 'a false trade-off' for cities, climate experts say**. Smart Cities Dive, 2023.
KŐ, Andrea; ANDRÁS, Gábor and SZABÓ, Zoltán. **Risk Governance and the Role of Digital Communication in Policy Life Cycle Managemet**. 2015.
KOROMA, Braima; RIGON, Andrea; WALKER, Julian; SELLU, Sudie Austina. **Urban Livelihoods in Freetown's Informal Settlement**. SLURC - Sierra Leone Urban Research Centre, 2018.
LACSON, Julius Jay; LIDASAN, Hussein Sinsuat; AYUNINGTYAS, Vidya Spay Putri; FELISCUZO, Larmie; MALONGO, Johann Heinrich; LACTUAN, Nove Joshua; BOKINGKITO, Paul; VELASCO, Lemuel Clark. "Smart City Assessment in Developing Economies: A Scoping Review". **Smart Cities, 2023**. pp. 1744–1764.
LECK Hayley; SIMON David. "Fostering Multiscalar Collaboration and Co-operation for Effective Governance of Climate Change Adaptation". **Urban Studies**, 2013. pp. 1221-1238.
LÓPEZ, Ramón; THOMAS, Vinod; TRONCOSO, P. **Climate Change and Natural Disasters.** 2018.
MCNEILL, Donald. "Global firms and smart technologies: IBM and the reduction of cities"**. Royal Geographical Society**, 2015.
MCR2030 **We are a global partnership to strengthen local resilience.** s.d. .
MIYAMOTO, James; BUCKMAN, Stephen. **"Rio de Janeiro's attempt at Favela urban upgrading". Cities - Communities and territories**, 2022. pp. 161-180.
MYERS, Norman. **Environmental refugees:** a growing phenomenon of the 21st century. The Royal Society, 2002.
NUGROHO, Yanuar. **The Cianjur Earthquake Reveals the Inadequacy of Disaster Resilience in Indonesia**. FULCRUM - Analysis of Shoutheast Asia, 2022.
O Globo. **Rio vive a pior enchente da história.** O Globo, 2010.
OGIE, R.I.; CLARKE, R.J.; FOREHEAD, H.; PEREZ, P. . **Crowdsourced social media data for disaster management:** Lessons from the PetaJakarta.org project. Computers, Environment and Urban Systems, 2018.

PALLARDY, Richard; RAFFERTY, John P. **Chile earthquake of 2010.** Britannica, 2024.
Peta Bencana **About.** Info.Petabencana. . Available at: https://info.petabencana.id/about/.
PICIULLO, Luca; CALVELLO, Michele; NEIVA, D'orsi Ricardo Neiva; PAES, Nelson M.; MAGALHAES, Marcelo A.; COELHO, Rodrigo; LACERDA, Willy A. .**The Community-Based Alert and Alarm System for Rainfall Induced Landslides in Rio de Janeiro, Brazil**. Engineering Geology for Society and Territory. Springer International Publishing Switzerland, 2015. - Vol. 2.
PILKINGTON, Robert William. "Financing Flood Risk Investments in Bamako, Mali". **Results in Resilience Series**. Washington D.C., 2023.
UNDRR. **Poorly planned urban development**. Prevention Web, 2013.
RATCLIFFE, Rebecca. **Hundreds killed after Sierra Leone mudslide**. The Guardian, 2017.
RENALDI, Adi. **Indonesia's giant capital city is sinking.** Can the government's plan save it?. National Geographic, 2022.
RESILIENT CITIES NETWORK. **Resilient Cities Network**: Impact Report 2022-2023. New York, 2024
RIBEIRO, Paulo Jorge Gomes; PENA JARDIM, Gonçalves Luís António. "Urban resilience**:** A conceptual framework". **Sustainable Cities and Society**, 2019.
SAMARAKKODY, Aravindi; AMARATUNGA, Dilanthi; HAIG, Richard." Technological Innovations for Enhancing Disaster Resilience in Smart Cities: A Comprehensive Urban Scholar's Analysis". **Sustainability**, 2023. Ed 15. Vol. 12036.
SAMHSA. **Disaster Technical Assistance Center Supplemental Research Bulletin - Greater Impact:** How Disasters Affect People of Low Socioeconomic Status. Substance Abuse and Mental Health Services Administration, 2017.
SHAW, Rajib; IZUMI, Tanako. "Challenges and Potentials of Private Sectors in Disaster Management". **Disaster Risk Reduction**, 2015. pp. 333-342.
SONG, Zhijun; ZHANG, Hui; DOLAN, Chris. "Promoting Disaster Resilience**:** Operation Mechanisms and Self-Organizing Processes of Crowdsourcing". **Sustainability**, 2020. Vol. 12.
SHULTZ, James M.; COHEN, Madeline A.; HERMOSILLA, Sabrina; ESPINEL, Zelde; MCLEAN, Andrew. "Disaster Risk Reduction And Sustainable Development For Small Island Developing States". **Disaster Health**, 2016
STUTZ, Bruce. "With a Green Makeover, Philadelphia Is Tackling Its Stormwater Problem". **Yale Environment 360,** 2018. Available at: https://e360.yale.edu/features/with-a-green-makeover-philadelphia-tackles-its-stormwater-problem.
SWAPAN, Mohammad Shahidul Hasan. "Who participates and who doesn't? Adapting community participation model for developing countries". **Cities - The international journal of urban policy and planning**, 2016. pp. 70-77.
TAGHIZADEH, Abbas Ostad; ARDALAN, Ali; PATON, Douglas; JABBARI, Hossain; KHANKEH, Hamid Reza. **Community Disaster Resilience:** a Systematic Review on Assessment Models and Tools. 2015.
TOL, Richard S.J. . "A meta-analysis of the total economic impact of climate change". **Energy Policy**, 2024. Vol. 185.
TONMOY, Fahim Nawroz; HASAN, Samiul; TOMLINSON, Rodger. "Increasing Coastal Disaster Resilience Using Smart City Frameworks: Current State, Challenges, and Opportunities". **Frontiers in Water**, 2020.

UCLG ASPAC. “Twin Approaches: Climate Change Mitigation and Adaptation in Developing Countries”. **Pacific United Cities and Local Governments Asia**, 2024.
UN 69/283. **Sendai Framework for Disaster Risk Reduction 2015–2030.** Aseembly United Nations General, 2015.
UN DESA. **World Economic Situation and Prospects**. Department of Economic and Social Affairs of the United Nations Secretariat, 2021.
UN. **Main findings and recommendations of the midterm review of the implementation of the Sendai Framework for Disaster Risk Reduction 2015–2030**. New York: United Nation Genreal Assembly, 2023.
UN Press. **People, Countries Impacted by Climate Change Also Vulnerable to Terrorist Recruitment, Violence, Speakers Tell Security Council in Open Debate**. Release UN Security Council Press, 2021.
UN/DESA. **Country classification -** Data sources, country classifications and aggregation methodology. World Economic Situation and Prospects, 2014.
UNCTAD. **Handbook of Statistics 2017 - Population.** 2017.
UNCTAD. **Now 8 billion and counting:** Where the world’s population has grown most and why that matters. 2022.
UNDRR. **Disaster Risk Reduction in Least Developed Countries**. United Nations Office for Disaster Risk Reduction. Available at: https://www.undrr.org/disaster-risk-reduction-least-developed-countries.
UNDRR. **Local authority and urban practitioner perspectives on risk reduction since 2015:** Recommendations for a mid-course correction. United Nations Office for Disaster RIsk Reduction, 2023.
UNFCCC. **United Nations Framework Convention of Climate Change.** 1992.
MAPLECROFT Verisk. **84% of world’s fastest growing cities face ‘extreme’ climate change risks**. 2018. Available at: https://www.maplecroft.com/insights/analysis/84-of-worlds-fastest-growing-cities-face-extreme-climate-change-risks/.
WAYMAN, Erin. **Chile's quake larger but less destructive than Haiti's**. 2012.
WHO. **Climate Change**. World Health Organization, 2023. Available at: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.
WMO. **WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019).** World Meteorological Organization (WMO), 2021.
WOETZEL, Lola; REMES, Jaana; BOLAND, Brodie; LV, Katrina; SINHA, Suveer; STRUBE, Gernot; MEANS, John; LAW, Jonathan; CADENA, Andres; VON DER TANN, Valerie. **Smart cities:** Digital solutions for a more livable future.McKinsey Global Institute, 2018.
World Bank. **Early Warning System Saves Lives in Mozambique**. 2023. Available at: https://www.worldbank.org/en/news/feature/2023/09/11/early-warning-system-saves-lives-in-afe-mozambique.
World Bank. **Results In Resilience:** Charting A Path To Coastal Resilience In The Gambia. GFDRR, 2022. Available at: https://www.gfdrr.org/en/feature-story/results-resilience-charting-path-coastal-resilience-gambia.
WWF. **What’s the difference between climate change mitigation and adaptation?**. Available at: https://www.worldwildlife.org/stories/what-s-the-difference-between-climate-change-mitigation-and-adaptation.

ZORN, Matija. Natural Disasters and Less Developed Countries. *In:* [Pelc, Stanko; Koderman, Miha] **Nature, Tourism and Ethnicity as Drivers of (De)Marginalization**: Insights to Marginality from Perspective of Sustainability and Development.

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[1] See more on subsection 2.1 Information and communication technologies applied to natural disasters.
[2] Most homes in the city are built with semi-permanent structures like iron sheets (Koroma, *et al.*, 2018), which poorly perform temperature-wise.
[3] In terms of earthquakes, the city is more than 100 miles far from fault lines, which make those events less intense than in other parts of the country (Nugroho, 2022).
[4] See more on subsection 2.1 Information and communication technologies applied to natural disasters.
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