

Informal Settlements, Growth, and Vulnerability: A Model for Risk-Sensitive Growth of Brazil's Favelas

Master's thesis in Development Economics and International Cooperation

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Abstract

This study aims to advance an understanding of the impact of self-built housing's incremental growth on disaster vulnerability, focusing on the case study of Rocinha, a favela in Rio de Janeiro. The purpose of investigating disaster vulnerabilities is twofold: disasters not only threaten development, but the vulnerabilities that drive disaster risk are also the same factors that impact living standards and allow development. This study establishes a theoretical framework that connects informal settlements' incremental growth and vulnerabilities to hazards, examines existing literature on its characteristics, and analyzes existing policy measures and initiatives to address it. It then highlights the gap in academia and practice in addressing the informal settlements' incremental growth and its outcomes and examines the local context and vulnerabilities to hazards in Rocinha, using primary sources collected through fieldwork and resident's questionnaire. Finally, it suggests a model for risk-sensitive growth in Rocinha that builds upon the incremental self-built housing process.

Keywords: Urban Informality; Self-Built Housing; incremental Growth; Vulnerability; Disaster Risk; Favelas

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Preface

On a steep landscape between jungle and ocean, between two of the wealthiest neighborhoods in Rio De Janeiro, Gávea and São Conrado, there is a community, a favela named Rocinha. No one knows precisely how many people live in the 1.4 square km of Rocinha; estimates predict up to 350,000 residents, making Rocinha the largest favela in Brazil and one of the largest in Latin America. For a while, I was one of those residents; Rocinha is where I called home. This study originated from a personal need to better understand the socio-spatial and growth processes of the built environment in which I participated, as an architect, by assisting and counseling friends and neighbors on various home renovations and expansions. It is dedicated to the residents of Rocinha, who continue, with great self-resilience, to build their houses and community.

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1. Introduction

Disaster and development are closely related, particularly in the context of urban informality. While urban informality may be perceived as the fastest growing form of new urban development (Dovey and King, 2011), informal settlements are recognized for both their development potential to increase disaster risk and their high level of vulnerability to disasters (Gencer, 2013; Johnson et al., 2020; Smyth and Royle, 2000). When a disaster occurs, it cancels out the progress made. As UNDRR (n.d.) articulates, "Disasters threaten development, just as development creates disaster risk."

In this study, I focus on the built environment, with the vision to bridge between the disaster risk management and architecture domains. Between a domain that sees urban informality, on its vernacular architecture and incremental growth, primarily for the problems it poses, to a domain that commonly romanticizes it and sees its embedded possibilities. I use UNDRR's framework for Disaster Risk, focusing on the vulnerabilities to disaster. The focus on vulnerabilities is not only because disasters impede development but also because the vulnerabilities that drive disaster risk, such as lack of infrastructure and services provision, are the same factors impacting residents' living standards and allowing development. Therefore, the framework of disaster risk is a means to two ends.

In Brazil, more than 85% of the population builds and renovates without the guidance of architects, urban planners, or engineers (CAU/BR, n.d.). In Rio de Janeiro alone, 22%-24% of the population lives in favelas (Williamson, 2021), where incremental self-built housing is a common practice. Rocinha is one of more than a thousand favelas in Rio and the largest favela in Brazil. It presents an interesting case study and a possible future for other favelas in Brazil and even other informal settlements worldwide for its level of consolidation and vulnerabilities characteristics.

Project appraisal methods inspired this study perspective. In a way, this study aims to discuss the marginal social cost of building another floor, or even a room, in a favela house. It suggests that due to favelas' unique growth and development model, each private construction has imperative economic implications in the form of externalities to society. Though the process of incremental

growth of self-built houses has the potential to increase or reduce vulnerability and, therefore, disaster risk in informal settlements, existing policies and programs in Brazil do not tackle the process itself, the private expansion of houses, only its outcomes.

Thus, this study aims two-fold; to advance an understanding of the impact of self-built housing and incremental growth on disaster vulnerability and propose a model for risk-sensitive growth in Rocinha, Rio de Janeiro.

To advance an understanding of the topic, I examine existing literature from both academia and practice. Through the literature, I establish a theoretical framework that connects informal settlements' incremental growth and vulnerabilities to hazards, discuss the characteristics of vulnerability to hazards in informal settlements, and analyze existing policy measures and initiatives and their potential to address the vulnerability at a community level. I also highlight the gap in academia and practice in addressing the impact of the process of informal settlements' incremental growth on disaster vulnerability. I then examine the local context and vulnerabilities to hazards in Rocinha using primary sources collected through fieldwork and residents' questionnaire. Finally, I propose a model for risk-sensitive growth in Rocinha that builds upon the incremental self-built housing process.

Since this study focuses on a specific community within the context of urban informality, various secondary sources were examined to avoid biases and a lack of information, ranging from academic research, federal laws, and international organization guidelines to community-based initiatives publications and social media. These sources were then reflected upon using the collected empirical data and vice versa.

The limited scope and the short period of this study did not allow for an in-depth examination of socioeconomic and cultural aspects such as the existence of drug gangs (mafia), Brazil's unique history of colonialism and slavery, which shaped socioeconomic inequities, and land tenure. On the latter, I chose not to elaborate due to the level of consolidation in Rocinha. Nonetheless, this study provides valuable insight and contribution.

The contribution of this study is not only its addition to the growing body of knowledge regarding disaster risk management in the context of urban informality but also in suggesting a model for risk-sensitive growth for future implementation or adaptation of further studies in different contexts. Furthermore, Since Rocinha's development is almost at capacity, where buildings reach 4-8 stories, it represents a possible future for other informal settlements in the global south. Therefore, this study provides an understanding of key development, growth, and vulnerability characteristics that can inform the future work of different actors as practitioners, local initiatives, NGOs, governments, and academics.

The following chapters will commence by presenting a background of the history of favelas and Rocinha (chapter 1.1). Following that, a literature review discusses the theoretical framework, existing studies, and practices regarding disaster risk management in informal settlements (chapter 2). Then, analysis of the local vulnerabilities to hazards in Rocinha (chapter 3) and a model proposal for Rocinha's risk-sensitive growth (chapter 4). Finally, this study will conclude with a discussion on conclusions, limitations, and possible ways forward (chapter 5) and References (chapter 6).

1.1. Background: A short History of Rio's Favelas

This chapter will present a brief reflection of the main aspects of Rio's favelas' history, development, form, and governance, focusing on Rocinha to portray a general background to this research work.

Informal settlements began to appear in Brazil in the 19th century against the backdrop of the abolition of slavery and the lack of affordable housing solutions (Williamson, 2021). In the 20th century, while Rio de Janeiro was the capital of Brazil, they have expanded throughout Rio's city center, and the word 'Favela' was officially adopted (Burgos, 2016), but it was only in the 1940s, with a wave of urban migration that caused a housing crisis, that favelas grew substantially and became the common residence typology for the lower class (Pino, 1997). A change in the urban approach to

favelas can be recognized in the mid-1980s when the government had moved from favelas removal programs to favela urbanization projects (Dos Santos, 2007). Following this approach, from the end of the 20th century, residents of favelas had been introduced to various programs and policies for favelas upgrading; *Favela Barrio*, *Morar Carioca*, security and growth programs; *UPP*, *PAC*, social housing; *Minha Casa, Minha Vida*, and assistance; *Bolsa Família* (Burgos, 2016). Today, more than one thousand favelas are spread across the metropolitan area of Rio, housing 22%-24% of the population. They had become a place of living not only to the lower but also to the middle class (Williamson, 2021; O'Hare & Barke, 2002). Williamson (2021) argues that favelas suggest a local model to the rule of thumb, stating that at least 20% of any population cannot afford market-rate housing.

While there has been much research on informal settlements, they remain largely unstudied in terms of urban form (Poiani, 2019). It is a common argument among scholars that urban informality and favelas have their own logic and rules that shape their spatial form (Cavalcanti, 2019; Jacques, 2011; Lara 2009), yet, the discussion on the form logic and characteristics is somewhat limited. Nonetheless, I would like to highlight a few characteristics that I believe are essential as a background to this study.

Lara (2009), in his study *The Form of the Informal*, suggests that building practices had arrived at the favela from masons working in the city. He argues that it is an adaptation of a modernist style scheme of independent concrete columns and beam structure with brick walls. The interior organization follows a nineteenth-century Brazilian building tradition, with bedrooms opening directly into the dining room and kitchen and bathroom located at the back of the building (Lara, 2009). Over the decades, favela houses had transformed from wooden shacks to concrete houses and even buildings (De Sherbinin et al., 2007). Their constant process of transformation (Jacques, 2011), an incremental growth mechanism (Poiani, 2019), is one of their main characteristics, whereas expansions typically occur vertically by building on top of the rooftop (Martins and Saavedra Farias, 2019; O'Hare & Barke, 2002). Cavalcanti (2016) contributes to the body of knowledge by showcasing

how labor is a key aspect that shapes the favelas. Ground floors often accommodate commercial uses, production or animal raising areas integrated within the household, and rooftops (Laje) valued for recreation and social gatherings. Cavalcanti (2016) also establishes that residents prefer to invest in income generation activities, such as expanding houses for renting purposes, rather than for family growth reasons.

With a history ranging from neglect to low intervention from the government, Favelas had developed their own governance mechanisms over the decades. Even though this varies from one favela to another, five common governance and political actors can be identified in favelas: (1) The Church, churches started to operate inside the favelas around the 1940s, introducing Catholicism, providing services, and creating linkage to the government (Pino, 1997). (2) Resident's Associations, which started to govern the favelas in the 1960s, were initiated mainly by the government in an attempt to create a governing body that would conform to their agendas (McCann, 2006). (3) 'Mafia' (drug gang) arrived at the favelas in the 1980s, recognizing the political power of the resident's associations they sought to control them (ibid.). (4) NGOs started to operate intensively inside the favelas in the 1990s and became key actors (ibid.). (5) UPP (Police Pacification Unit), the public security program started in 2008 aiming to control crime and contribute to the security of residents and the city by a constant presence of police (Burgos, 2016). These five actors form complex dynamics between state, religion, organized crime, and civil society.

Rocinha, the largest favela in Brazil, with more than 100,000 residents¹, was originally farmland at the city's outskirts (IMS & SN, n.d.). As the city expanded into the south, Rocinha had gained a prime location in the wealthy zone of Rio, leading to substantial growth in population over the years (Burgos, 2016). In 1993 Rocinha was officially designated as a 'Bairro', a neighborhood. The location and size of Rocinha led, and are still leading, to the extensive activity of commerce, tourism,

¹ The most recent census from 2008 to 2009 for the PAC program counted 98,319 residents, although the statistics face difficulties to produce a reliable picture of reality (Burgos, 2016), in media estimates range from 150,000 and up to 350,000.

drug trade, and NGOs inside the favela, particularly since the mid-1990s (Burgos, 2016; IMS & SN, n.d.). Rocinha has seen substantial spatial and governance changes in the past two decades. A state designation of special interest ecological area at the border of the favela had limited its horizontal expansion (IMS & SN, n.d.) and can be explained as one of the main factors that led to the neighborhood's vertical growth. In 2004 (Burgos, 2016) and 2017, two 'mafia wars' had resulted in a change in the organization that controls the favela. Under policies to present the city as safe and sanitized for the world cup and the Olympics, in 2011, the UPP and the Acceleration and Growth Program (PAC) had arrived at Rocinha, which implemented a few large-scale development projects (IMS & SN, n.d.).

Led by self-built housing mechanisms, Rio's favelas continue to grow, portraying a model of incremental growth and a possible future for many communities worldwide. The next chapters will discuss the link between incremental growth and communities' vulnerability.



Figure 1. *Rocinha, Location and Context (left)* (Illustration on Google Earth image,2019).

Figure 2. *View of Rocinha (right)* (Reis, 2018).

At this point, I would like to clarify the use of the term 'Favela' in this paper. The term 'Favela' is highly contested by the local population and in the media. Though while living in Rocinha, I used the term 'Comunidade' (meaning 'community'), in this study, I chose to use this term for two reasons; (1) Since it represents a particular setting in Brazil, brought about from a specific history and culture and

with its unique socio-spatial characteristics in different from 'slums' or 'shantytowns'. (2) Since it is commonly used among scholars, it allows me to respond and contribute to the existing academic discussion.

2. Literature Review

This literature review examines the principal issues regarding disaster vulnerability in the context of urban informality, particularly in Brazil's favelas. This chapter comprises four sub-chapters that produce a conceptual course of knowledge examination; Chapter 2.1. establishes the theoretical frameworks; disaster risk and urban informality, Chapter 2.2. discusses main characteristics of vulnerability in favelas, Chapter 2.3. examines policies and projects to reduce disaster risk in favelas, and Chapter 2.4. discusses Bias and Literature Limitations.

2.1. Theoretical framework: On Disaster Risk and Urban Informality

The potential of rapid urbanization and demographic growth to increase vulnerability to disasters, particularly in the context of urban informality, is commonly stated. References to it can be found in literature in practice and academia, such as the UNDRR (2019), Gencer (2013; 2017), Johnson et al.(2020), Smyth and Royle (2000), and Abunyewah et al. (2018). However, while the notion of urbanization is fairly common, the concept of disaster risk and the definition of urban informality differs according to scholars and contexts, therefore requiring further elaboration. Though each of these two frameworks may have been the subject of a separate academic study, for the purposes of this study, this chapter will present the concepts on which this research is based.

Disaster Risk and Vulnerability

The terms *Disaster Risk Reduction* and *Resilience* are frequently used interchangeably in the urban development field.

Resilient Cities Network (n.d.) defines urban resilience as “the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of **chronic stresses** and **acute shocks** they experience”. Acute shocks are sudden, intense events that threaten a community, such as earthquakes, hurricanes, and terrorist attacks. The impact of acute shocks is exacerbated by chronic stresses that weaken the fabric of a community over time, such as recurrent flooding, high unemployment, limited social safety nets, and inequitable public transportation systems.

The UN Office for Disaster Risk Reduction (UNDRR) defines Disaster Risk as the possibility of a disaster causing loss of or impact on human (life), material assets, economy, and environment (UN General Assembly, 2016). Risks are the consequence of the interaction between several components; the severity and frequency of a **hazard** (for example, cyclones, earthquakes, floods, or fires), the **exposure** of people and assets to hazards, and the **vulnerability** of the exposed population or assets. Hazards do not have to turn into disasters; the risk components are not static and may be improved based on institutional and individual **coping capacity** and/or act to reduce risk and increase resilience (Gencer, 2017, 9). The following formula can illustrate this:

$$\frac{Hazard \times Exposure \times Vulnerability}{Coping Capacity} = Disaster Risk$$

An examination of both frameworks allows us to outline similarities between the terms ‘chronic stresses’ and ‘vulnerabilities’ as well as between ‘acute shocks’ and ‘disaster’. In this study, I chose to follow the UNDRR framework and definition of disaster risk because it allows a better understanding and representation of the role of vulnerability and other components of risk in how a disaster unfolds.

Though the formula offers a straightforward approach, recent decades and events such as Covid19 highlighted the systemic nature of disaster risk. Events overlap and interact with other risk drivers such as poverty, climate change, population growth in hazard-exposed areas, uncontrolled urbanization, and biodiversity loss (CRED, UNDRR, 2020, 7). UNDRR (2019) defines systemic risk as the risk that is endogenous to, or embedded in, a system but is not considered a risk in itself and

hence is not generally tracked or managed. Systemic risks are emergent and not necessarily obvious using contemporary hazard-plus-hazard approaches until the disaster occurs.

With the acknowledgment of the challenges to understand and manage systemic risk (CRED, UNDRR, 2020), the scope of this study will not be on disasters risk management as a whole but will focus on a particular component of risk, on vulnerability, recognizing the opportunities and increasing need to address this component in the context of urban informality as will be discussed later on.

The UN defines disaster vulnerability as the conditions caused by physical, social, economic, and environmental elements or processes that raise the sensitivity of an individual, a community, assets, or systems to the effects of risks (UN General Assembly, 2016, 24). Development patterns can increase exposure and vulnerability; for example, if not met with sustainable planning and land-use decisions, rapid urbanization can put pressure on land, infrastructures, and services, resulting in increased vulnerabilities and, hence, increasing or creating new risks (Gencer, 2017, 9).

However, urbanization poses not only a challenge but also opportunities for sustainable development. In order to further discuss the challenges and opportunities to urban development, the framework and specific context of urban informality in this study need to be defined.

Urban Informality and Incremental Growth

“Definitions of the term ‘formal’ and ‘informal’ appear to be challenging to architecture” (Lara, 2009, p.23). This study adopts Ananya Roy’s (2005) conceptual framework of urban informality as ‘a mode of urbanization’. The framework suggests that the informal is not a separate sector from the formal, nor it necessarily needs to be formalized, the use of the term urban informality “indicate an organizing logic, a system of norms that governs the process of urban transformation itself” (Roy, 2005, p.148). Roy’s conceptualization offers an opportunity to perceive urban informality as a model for urban development rather than a problem or a challenge. UN Habitat’s data (2013) indicates that around a billion people globally live in ‘squatter’, ‘slum’ or ‘informal’ settlements, accounting for one-third of the world’s urban population. These numbers emphasize that urban informality cannot be perceived as a mere phenomenon and be eradicated or “formalized”. Dovey and King (2011) claim

that informality is the fastest growing form of new urban development. Williamson's rule of thumb (2021), stating that at least 20% of any population cannot afford market-rate housing, further support the claim for urban informality as a model for urban development.

Johnson et al. continues Roy's conceptualization and contribute to the discussion by arguing that urban informality manifests not only in the form of informal settlements but in many types of processes, including but not only informal construction, informal economic activity such as street vending or home-based enterprises, community-based upgrading efforts and community-installed infrastructure (2020, 56). Though urban informality is commonly thought to be for the poor or lower to middle-class, scholars emphasize that it also includes upper-class or elite expressions in forms such as illegal land grabbing or un-approved planning and construction of villas, gated communities, and commercial buildings (Johnson et al. 2020; Roy, 2005; Alvarez & Cardenas, 2019). Apart from the socio-economic differences, these expressions differ from the formerly discussed informal settlements by two main aspects; (1) Their construction technologies are usually more advanced, allowing less structural vulnerability and less impact on their environmental vulnerability (Smyth and Royle, 2000). (2) They are more often than others being treated differently by local governments. Instead of eviction and demolition, local governments build, repair, and upgrade infrastructures as well as dig out and move natural drainage lines and basins. While it is essential to acknowledge that these manifestations are part of urban informality, since they follow different characteristics, face different aspects of disaster vulnerability, and present different extent and dimensions, they will not be the focus of this study. Nevertheless, this elaboration of the framework contributes to the understanding and definition of informal settlements.

According to Dovey and King (2011), 'informal settlements' are urban fragments or districts that develop and operate primarily outside the government's formal control. The majority of them include a variety of renting, squatting, and informal rights; tenure is frequently irregular and contested rather than strictly illegal. However, Handzic (2010), in his study of Brazil's favelas land tenure, revealed that due to several government programs, some of the residents in favelas did acquire legal

tenure. Another common characteristic of informal settlements is their tendency to be located on marginal and vulnerable land, previously avoided by formal development (Gencer, 2013; Smyth and Royle, 2000; Satterthwaite et al., 2020; Abunyewah et al., 2018).

Now that the framework of urban informality as a model for urban development has been established, I would like to examine the system of norms that drives it, among them the mechanism of incremental growth, led by the process of self-built housing. From a global perspective, the primary expansion and consolidation process in informal settlements is incremental and is led by residents' private construction and expansion of houses according to their social needs and accumulation of financial resources. Whereas it occurs room by room, floor by floor, or house by house, it presents a constant process of transformation and growth. (Pojani, 2019; Dovey and King, 2011; Jacques, 2011). Jacques (2011) refers to these characteristics in her discussion of Brazil's Favelas, adding that Favela houses not only present a unique growth and development model, they also constitute their own aesthetics and design logic, which are essential to understand and consider for practitioners and scholars in the field.

Theoretical Framework

Building upon the two theoretical frameworks; Disaster Risk and Urban Informality, I will make two fundamental arguments on the focus of disaster risk policies and measures in the context of urban informality:

First, Abunyewah et al.'s (2018) literature synthesis indicates that disaster hazards are difficult to prevent. Considering that even though informal settlements tend to locate in hazardous areas, the share and quantity that these localities constitute in the urban environment does not simply allow to relocate them or to reduce their exposure extensively. It suggests that disaster risk policies and projects should focus on reducing vulnerabilities and increasing coping capacity. As an illustration, based on the UNDRR formula for understanding risk, in the case of informal settlements, hazard and exposure are 'given', and can be seen as constant or semi-constant.

$$\frac{\textit{Hazard} \times \textit{Exposure} \times \textit{Vulnerability}}{\textit{Coping Capacity (Resilience)}} = \textit{Risk}$$

Second, The system of norms that drives urban informality is critical to this study discussion as it presents a unique development model; a privately-led continuous process of growth. Building upon this theoretical framework, I argue that projects and policies aiming at disaster risk reduction in the context of urban informality should respectively offer a responsive and adaptive mechanism that focuses on the private incremental construction process. In other words, every additional floor or even a room constructed in a favela has the potential to increase or reduce the vulnerability of the entire community. Since favelas continue to grow, efforts to reduce vulnerability should intervene with that process.

In the next chapter, I will further examine disaster risk and vulnerabilities in the context of urban informality on its incremental growth and self-built housing.

2.2. On Favelas, Incremental Growth, and Vulnerability

A substantial amount of studies state that informal settlements are highly vulnerable to disasters (Gencer, 2013; Johnson et al., 2020; Smyth and Royle, 2000; Satterthwaite et al., 2020; Abunyewah et al., 2018), a result of unplanned urbanization schemes (Gencer, 2013; Abunyewah et al., 2018; Johnson et al., 2020) and market and public policy failure (Williamson, 2021; Wekesa et al., 2011; Williams et al., 2019). Rio de Janeiro, and notably Rio's favelas, suffers from high vulnerability to climate hazards, particularly flooding and landslides (Williams et al., 2019; Bittencourt et al., 2013). This chapter investigates informal settlements' vulnerability characteristics as well as scholars' recommendations for policy measures, with a focus on the case of Rio's favelas.

Though there are several categorization frameworks in the reviewed literature, for the purpose of this study, informal settlements' vulnerability to hazard are categorized into four areas: *spatial-environmental, infrastructures and services, structure, and socio-economic*. Following UNDRR's framework for disaster risk, exposure and vulnerability characteristics are further distinguished.

Spatial-Environmental

Spatial-Environmental characteristics encompass location and environmental-related practices that increase both exposure and vulnerability components.

The physical location of informal settlements renders their high exposure to hazards. The tendency of informal settlements to locate in hazard risk areas was previously discussed. Such areas, as hillsides or slopes subjected to slope failure and flooding (Smyth and Royle, 2000), flood plains, marshy areas, low-lying areas, river courses, or other hotspots of natural hazards such as fire, earthquakes, and tsunamis (Abunyewah et al., 2018). Residents favor these locations due to their availability and affordability; official development usually avoids them, resulting in a lower risk of eviction (Abunyewah et al., 2018; Gencer, 2013). Furthermore, their proximity to 'formal' areas allows access to services and the labor market (Satterthwaite et al., 2020).

Fahlberg et al. (2020) and Smyth and Royle (2000) elaborate on Rio de Janeiro's local characteristics where informal settlements are located not only on the city outskirts as in most cities but also on hillsides in the middle of the city. Their central location impacts residents' economic resources and access to transportation and other services.

Human occupation activities, coupled with the exposure characteristics, increase informal settlements' environmental vulnerability even further, bringing degradation of land and soil erosion. Vegetation clearance for construction purposes often allows rapid soil erosion, increasing the potential for landslides. Paving of land surfaces during construction, though, has the potential to reduce landslides (Smyth and Royle, 2000), also reduces infiltration and increases run-off water channeled (Abunyewah et al., 2018; Smyth and Royle, 2000; Williams et al., 2019; De Sherbinin et al., 2007). Smyth and Royle (2000) further examine the development and consolidation of favelas, observing that the transition from shacks to houses built with more heavy materials such as concrete places additional stresses on the local environment.

Spatial-Environmental characteristics of informal settlements' vulnerability pose a challenge to policy makers as they primarily affect the exposure of the settlements to hazards. Although these

characteristics might seem like a 'given' or constant, they are constantly exacerbated as informal settlements grow larger and denser, accounting for the high percentage of urban population growth. (Gencer, 2013; Abunyewah et al., 2018; Johnson et al., 2020)

Though resettlements of inhabitants have been found to be inefficient as a policy solution (Gencer, 2013; Satterthwaite et al., 2020), reducing exposure to a certain extent can be achieved using methods such as "upstream" watershed management to redirect floodwater flows (Satterthwaite et al., 2020; Alvarez and Cardenas, 2019). Such structural measures are usually set outside of community boundaries and therefore should be considered by local governments along with other infrastructural measures to reduce physical vulnerability.

Infrastructures and services

Informal settlements are commonly discussed for their inadequate or lack of infrastructures and services provision, which not only affects residents' living standards but also increases their susceptibility to disasters (Gencer, 2013; Abunyewah et al., 2018; Smyth and Royle, 2000; Satterthwaite et al., 2020; Fahlberg et al., 2020). Lack of adequate infrastructure and services provision is evident by both the lack of their initial development and their limited holding capacity as informal settlements continue to grow larger and denser.

Inadequacy or lack of infrastructures such as sanitation, water, and waste management, coupled with inadequate drainage network and maintenance (Gencer, 2013; Abunyewah et al., 2018; Smyth and Royle, 2000; Satterthwaite et al., 2020; UN-Habitat, 2003; Wekesa et al., 2011), result in environmental and health problems (Gencer, 2013) and further reduces the ability of run-off water to move swiftly (Abunyewah et al., 2018; Satterthwaite et al., 2020). Insufficient natural ventilation and sunlight were also indicated as a vulnerability by Martins and Saavedra Farias (2019). These can further affect health and the ability to bounce back from water-related disasters.

Unstable electricity provision (Smyth and Royle, 2000; Satterthwaite et al., 2020; Fahlberg et al., 2020) and inadequate roads infrastructures (Smyth and Royle, 2000), coupled with lack or

inefficient public urban services such as transportation networks, hospitals, fire or police stations translate into lack of response capacities in case of disasters (Gencer, 2013).

Satterthwaite et al. (2020) further note that the lack or inadequacy of healthcare and education services can further exacerbate the vulnerability of residents and the community as a whole.

Yet, in the absence of 'formal' infrastructures and services providers (ibid.), and with difficulty to get serviced by public or private companies due to the location of residency (Fahlberg et al., 2020), alternative, primarily informal, enterprises emerged to address the local needs. While these local enterprises 'relieve' some of the pressure, they are unable to provide the volume of infrastructure systems necessary, nor can they operate outside of their locality (Satterthwaite et al., 2020).

Structure

Structural characteristics of informal settlements encompass vulnerabilities emerging from construction practices and inadequate building materials (Gencer, 2013; Smyth and Royle, 2000; Satterthwaite et al., 2020; Wekesa et al., 2011).

Smyth and Royle (2000) discuss common practices of slope modification that increase vulnerability in informal settlements in the area of Rio de Janeiro. The 'cut and fill' technique, in which soil is removed from the back of the site and used as a filling at the front, although providing more 'flat' land for building, is highly susceptible to collapse for its unconsolidated nature. (ibid.). The standard method for excavating a vertical headwall causes significant property damage if it collapses. The construction on drainage canals or in proximity to large rock outcrops further render the structure vulnerable (ibid.).

Construction techniques are further discussed by Lara (2009) in his study of the architectural structure of the favelas. Lara demonstrates how the standard practice of local builders does not utilize structural properties; for example, reinforced concrete columns and beams are not constructed as independent structures using the hollow clay brick walls as load-bearing. These findings may imply buildings with a lower structural strength that are more rigid to changes and expansions that tend to occur in the lifetime of informal settlement houses.

Building design and materials may add to the vulnerability of the structures. The use of recycled materials in favelas (Jacques, 2011) may imply lower insulation and structural strength. According to climate properties, the use of uninsulated materials and poor ventilation may contribute to higher indoor temperatures (Satterthwaite et al., 2020) or water penetration and dampness. Location of electricity wires and food storage at a lower height in areas susceptible to floods can also increase vulnerability (ibid.).

Socio-Economic

Dwellers of informal settlements are characterized mainly as low-income with precarious livelihood (Abunyawah et al., 2018; Wekesa et al., 2011). Williamson (2021) states that in the case of Brazil's favelas, they are characterized by both lower and middle-class residents. Whether low or middle class, both scholars agree that residents of informal settlements have limited economic capabilities and low access to political power.

Low economic capabilities impact the ability of residents to invest in structural mitigation measures, prepare adequately for hazards, or bounce back in case of damage to structure or assets due to disaster (Abunyewa et al., 2018). Lack of access to political power affects spatial and societal resource allocation, resulting in differential hazard vulnerability (Smyth and Royle, 2000).

However, socio-economic characteristics of vulnerability to hazards do not end with that. Social and political exclusion, concentrated poverty, and lack of infrastructures such as transportation limit participation in the labor market, leading to a further decrease in economic capabilities, resulting in even higher vulnerability to hazards (Fahlberg et al., 2020). Poor education levels coupled with culturally and linguistically diverse minority groups impede the capability of informal communities to comprehend warning information and access to preparation and recovery information (Abunyawah et al., 2018).

Scholars have extensively discussed the impact of tenure security on disaster vulnerability. Though land tenure is not indisputably a socio-economic factor, it is addressed under this category for the relevance of its outcomes primarily to socio-economic characteristics of disaster vulnerability; it

holds the potential to influence behavior and prevent access to social and political rights that further increase vulnerability. Lack of tenure security in informal settlements poses a frequent threat of eviction, which discourages settlers from making large investments, resulting in the construction of low-quality homes (Abunyewah et al., 2018). It may also indicate a lack of registered addresses, which can prevent residents from accessing government services such as infrastructure provision, education, healthcare, social protection, and voting rights (Satterthwaite et al., 2020).

All policies and activities to reduce disaster risk rely heavily on financial support. Whether it is infrastructure and services provision upgrade or home improvement activities for low-income residents, assistance from both public and private organizations are needed (Abunyewah et al., 2018). Satterthwaite et al. (2020) discuss a mechanism for local funds in the form of community-managed savings groups. Such a mechanism, supported by local government and managed by community groups, can facilitate residents' housing and infrastructure improvement activities that decrease vulnerability and improve livelihoods, education, and welfare.

Table 1 presents a synthesized summary of the main Characteristics of informal settlements' vulnerability to hazards and policy measures proposed by the scholars reviewed in this chapter, following the four outlined categories.

Table 1.

Characteristics of Informal Settlements Vulnerability to Hazards and Proposed Policies

Vulnerability Category	Vulnerability Characteristics	Incremental Growth Effect	Policy Measures
Spatial-Environmental			
Location in hazard risk areas.	Location of high exposure to disasters; hillsides or slopes subjected to slope failure and flooding, flood plains, marshy areas, low-lying areas, river courses, other hotspots such as fire, earthquakes, and tsunamis.	Urban population growth brings further expansion of informal settlements on hazard risk areas <i>No examination of vertical growth effect.</i>	Hazards redirection measures (such as upstream solution)
Human occupation activities.	Vegetation clearance increases slope failure risk. Paving of land surfaces increases run-off water channeled.	Might cause a change in risk, Slope failure due to vegetation clearance decreases with consolidation and paving, channeled run-off risk increases.	Hazards redirection measures (such as upstream solution)
Infrastructures and services			

Lack of inadequate infrastructures such as sanitation, water, waste management, drainage, electricity, and roads.	Resulting in environmental and health problems. Further reducing the ability of run-off water to flow swiftly. Hinders disaster response capacity.	Growth overburdens existing infrastructures bringing to lack of holding capacity. Increase lack of infrastructure provision. <i>No examination of the different levels of infrastructure; city, community, households, and their connection points.</i>	Infrastructures upgrading schemes. Policies or programs to increase formal housing supply or reduce the cost of key components.
Insufficient natural ventilation and sunlight	Resulting in health problems.	<i>Relevant to more developed settlements when vertical growth occurs.</i>	
Lack or inefficient public urban services such as transportation networks, hospitals, fire or police stations.	Hinders disaster response capacity.	Growth overburdens existing infrastructures bringing to a lack of holding capacity. Increase lack of infrastructure provision.	Infrastructures upgrading schemes. Policies or programs to increase formal housing supply or reduce the cost of key components.
Lack of inadequate healthcare and education services.	Hinders preparation capacity and further increases general vulnerability.	Growth overburdens existing services bringing to a lack of holding capacity. Increase lack of services.	Infrastructures upgrading schemes. Policies or programs to increase formal housing supply or reduce the cost of key components.
Structure			
Slope modification practices	'cut and fill' technique and excavating vertical headwalls increase slope failure risk.	<i>No examination of vertical growth effect or inter-structural effects</i>	
Construction techniques	Self-taught construction techniques reduce structures strength and increase the rigidity of structure to changes.	<i>No examination of the effect on vulnerability due to incremental growth or inter-structural effects</i>	
Building design and materials	Use of recycled or uninsulated materials combined with poor ventilation may contribute to higher indoor temperatures or to water penetration and dampness. Location of electricity wires and food storage can increase damage to assets.	<i>No examination of the effect on vulnerability due to incremental growth such as consolidation and change in materials or inter-structural effects</i>	Financing mechanisms that will allow access to more resilient materials. Policies or programs to increase formal housing supply or reduce the cost of key components
Socio-Economic			
Low economic capabilities	Impact the ability of residents to invest in structural mitigation measures, to prepare adequately for hazards, or to 'bounce back' in case of disaster	<i>No examination of growth effect.</i>	Financing mechanisms that will allow access to more resilient materials.
Lack of access to political power	affects spatial and societal resource allocation, which can result in differential hazard vulnerability	<i>No examination of growth effect.</i>	
Social and political exclusion, Poor education level coupled with culturally and linguistically diverse minority groups	Renders vulnerability; further decreases economic capabilities and impede communication for warning and preparedness	<i>No examination of growth effect.</i>	Communication policies
Tenure security	influence behavior; discourage investment in less vulnerable housing, and prevent access to social and political rights that further increase vulnerability	<i>No examination of growth effect - it has the potential to increase security.</i>	Land management and tenure schemes

Note. This table is adapted and synthesized from the examined literature in this chapter. Text in italic font presents the author's input. The table highlights the studies' lack of addressing vulnerabilities in the context of a continuous growth process and the need for policy measures that operate on different scales and promote collaboration between actors.

Though scholars discussed a wide range of characteristics of disaster vulnerability, the reviewed literature reveals three main limitations.

Following an extensive literature review, Abunyewah et al. (2018) conclude that though the overwhelming vulnerability of informal settlements is widely discussed, current studies have yet to ascertain which characteristics of informal settlements have the most significant impact on vulnerability. The findings of this chapter support this argument. Since specific characteristics are strongly reliant on local context and climate (Williams et al., 2019), or may change over time and development level, and because causality relationships are not always evident, particularly in the case of systemic risks, building a one-size-fits-all model may be impractical. However, the impact could be measured at a case study level, and a body of case studies may offer an alternative to a global evaluation. This study will attempt to examine not only the local vulnerabilities in Rocinha but also the extent of their impact.

In the reviewed literature, the vulnerability of infrastructures such as water, sanitation, and electricity was discussed as one system, omitting to differentiate vulnerability in the city level infrastructure, provision of these infrastructures on a community level, and the “plug in” process to these infrastructures on a household level. For example, while lack of electricity provisioning or blackouts reduces residents’ living standards and might impede communication for warning and preparedness or response efforts, informal connections of private houses to the electricity network might increase the risk of fires and electrocution. Policy measures to reduce the vulnerability of these two aspects should also address different actors and levels; while the former might require a local government and private companies’ action, the latter might target the local, sometimes informal, private sector and individual households. Recognizing the three levels and their connections can help policymakers build better policies and enhance collaboration among players.

Satterthwaite et al. (2020) and Martins and Saavedra Farias (2019) emphasize the importance of policy measures that operate at different scales: individual\household, community\neighborhood\settlement, and city\locality. Building on this argument and the limitations found in the reviewed literature, this study proposes that the various scales should be considered earlier in the vulnerability assessment process. However, policy design should also consider actors’

capacity. According to Satterthwaite et al. (2020), the success of community-based action depends on the community leaders' ability to mobilize their community to action and the community's willingness and capacity to participate. Collaboration between communities and local governments may also be challenging, as local governments are not always receptive or have the necessary capacity (ibid.).

Finally, a little discussion was found in the reviewed literature of how vulnerabilities evolve or are influenced by the continuous growth process, especially between different growth patterns. Scholars also examined vulnerability primarily on either a community or individual scale, omitting to consider synergies and trade-offs across scales or the consequences of one building development on the vulnerability of its neighbor. For example, building techniques and house expansion have the ability to affect the structural strength of their neighboring buildings or reduce their provision of natural light and ventilation, which can result in structural or health problems and affect the ability to recover after a disaster such as floods. The theoretical framework established the importance of focusing on the private incremental building process when discussing vulnerability to hazards in the context of urban informality. The limited discussion on it in the reviewed literature further reinforces the need to address it in this study.

Building on the body of knowledge gained in this chapter; a deeper understanding of disaster vulnerability characteristics in the context of urban informality, the following chapter will examine existing policies and projects aimed at increasing resilience or reducing disaster risk in the local context of Brazil's favelas, with focus on the case study of Rocinha, Rio de Janeiro.

2.3. What is being done? Existing policies and projects

According to Satterthwaite et al. (2020), most informal settlement upgrading programs, while not designed with the primary aim of disaster risk reduction, provide a sound foundation to which they can be integrated. Building on this claim and the characteristics discussed in the previous chapter, this study argues that hazard vulnerability reduction is a byproduct of policies and upgrading

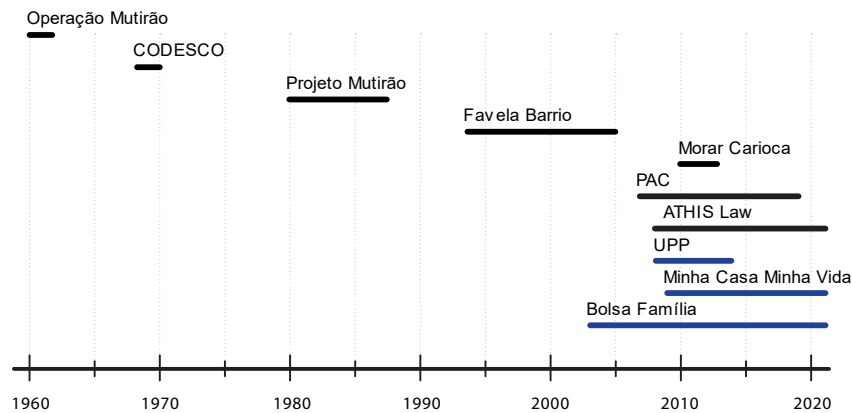
programs that enhance living standards and social equity. This chapter will review the central upgrading policies and programs that result in reducing vulnerability to hazards in favelas, focusing on Rocinha, Rio de Janeiro. Acknowledging that disaster risk reduction efforts are being undertaken at multiple levels and by various stakeholders, not only government-led policy measures will be examined, but also community-based initiatives and private and third-sector projects.

Government Policy Measures

A broad examination of the history of Rio's favelas reveals a shift in policy toward favelas in the early 1990s, from removal to upgrading. After decades of government neglect and the threat of eviction, the Organic Law of 1990, the primary legislation governing urban development in Rio, had enhanced the rights of favelas and stimulated several upgrading programs (Osborn, 2012a; CatComm, n.d.). In that context, it is essential to review the main favela upgrading and growth programs; *Favela Barrio*, *Morar Carioca*, *PAC*, the Law for Technical Assistance for Housing of Social Interest *ATHIS*, the environment resilience institute *Geo-Rio*, the security program *UPP*, the social housing program *Minha Casa Minha Vida*, and social welfare program *Bolsa Família*. The review will be done in thematic order. Figure 3. presents a timeline of the general programs reviewed.

Figure 3.

Main Policies and Programs Timeline



Note. This figure is adapted and synthesized from the examined literature in this chapter. Entities in black mark Upgrading schemes and laws, in blue mark additional relevant programs.

In addition to the main programs, when studying favela upgrading programs, it is helpful to begin in 1960. In the 1960s, two programs were initiated by Rio governors. *Operação Mutirão*, 1960, opted for community participation, and *Companhia de Desenvolvimento de Comunidades* (Community Development Company, or CODESCO), 1968, offered professional design support and long term, low-interest loans on construction materials to residents. Due to real estate pressure and political interests, these two ahead of their time programs were shut down with only little upgrading implemented (Osborn, 2012a). During the 1970s and 1980s, only small upgrading plans were implemented. Rocinha received infrastructure upgrades funded by UNICEF and implemented by Rio's municipality from 1979 to 1980 (ibid.). In 1982 the governor of Rio de Janeiro launched the municipal *Projeto Mutirão* program and *Cada Família Um Lote*, which implemented upgrading projects in 17 favelas (ibid.). It is the shift in policy toward favelas in the early 1990s that brought about the main upgrading programs.

Favela Bairro was launched in 1994 with the aim to support participatory on-site improvement initiatives (O'Hare & Barke, 2002; Osborn, 2012b; Soares & Soares, 2005) such as infrastructure upgrades, social services, and tenure regulation. (Osborn, 2012b; Soares & Soares, 2005; Burgos, 2016) Specific objectives included floods and landslides risk reduction, reducing vector-borne diseases incidents, increasing mobility, and utilizing public services (Soares & Soares, 2005). Though Rocinha was not directly benefited by this program (Burgos, 2016), its' scale and effect deem it essential to cover. The program, Undertaken by the municipality of Rio de Janeiro, was funded by the Inter-American Development Bank (IDB) and Rio government, coordinated by Municipal Housing Secretariat (Secretária Municipal de Habitação), and supported by COMLURB, the municipal trash-collection company, and state water company CEDAE. It was aimed at medium size favelas (500-2,500 inhabitants) and was divided into two phases, the first phase between 1994-1999, and the second phase from 2000-2005 (Osborn, 2012b).

Though the program increased water and sewer access leading to better health and sanitation. (Soares & Soares, 2005), it received criticism for its top-down administration (Osborn,

2012b) and its potential to cause gentrification (O'Hare & Barke, 2002). In contrast to the program's results and criticism, an IDB analysis revealed that the improvements had no impact on vector-borne disease mortality or did not change rental patterns. (Soares & Soares, 2005).

Morar Carioca, which was announced in 2010 with the ambitious objective of urbanizing all of Rio de Janeiro's favelas by 2020, was intended to draw on the lessons learned from the Favela-Bairro program and to continue its work. (Burgos, 2016; Osborn, 2013). It intended to use a participative approach, lower the surface area of favelas in the city by 5%, implement new zoning regulations, remove houses in high-risk areas, and resettle the removed inhabitants near their original homes (Osborn, 2013). Due to a lack of financial resources and political interests, the program stalled in 2013, achieving only a little of its aim (Osborn, 2013; Burgos, 2016). The primary distinction between Favela-Bairro and Morar Carioca was that the latter aimed to remove large sections of favelas due to their classified "areas of risk" (Burgos, 2016).

Programa de Aceleração de Crescimento (PAC), the 2007 federal Growth Acceleration Program (PAC) was announced for five favelas in the greater Rio, among them Rocinha (Burgos, 2016). The program, primarily financed by state companies and the private sector (ibid.), provided nearly \$300 billion worth of infrastructure upgrades and social assistance programs for low-income communities across the country. However, the interventions tended to be attention-grabbing. In the case of rocinha, PAC financed an iconic pedestrian bridge by the famous architect Oscar Niemeyer at the entrance to the favela (Osborn, 2012b), a sports complex at the border of the favela, reachable by the bridge (Burgos, 2016), and Rocinha's 4th Street (Rua 4 or R4) operation (Martins and Saavedra Farias, 2019).

R4 operation was designed and implemented between 2005 to 2010. It was a de-densification process in dense areas challenged by mobility and ventilation that resulted in health problems. The project includes street widening to improve ventilation and mobility, basic infrastructures such as roads, electricity, sanitation, and new buildings for public services and housing units. Though it

involved heavy demolition, the removal of many houses, and the relocation of the dwellers, it did not significantly improve the community's basic sanitation conditions, only its direct beneficiaries. (ibid.)

Lei de Assistência Técnica para Habitação de Interesse Social (ATHIS) was approved in 2008 (ATHIS, n.d.). The law ensures that low-income households have the right to free public technical support for the design, construction, renovation, and expansion of social housing for their own houses (Lei Federal 11.888 2008; CAU/BR, n.d.; ATHIS, n.d.). Despite the law's importance and potential, it is not effectively applied by the public authorities in Brazilian cities (CAU/BR, n.d.; ATHIS, n.d.). Among the causes for this is a lack of communication between public administration, technicians, and the general public and a lack of specific programs and financing (Borel, 2020). The professional entities that fought for the law founded the collaborative platform ATHIS to promote technical assistance.

GEO-RIO – Municipal Geotechnical Institute, Rio de Janeiro, was founded in 1966 to develop emergency and long-term slope protection plans, implement slope containment works, and map risks (Mendes Barbosa & Walker, 2020). After decades of no eviction programs, the 2010 heavy showers of rain that caused mudslides in Rio's favelas and killed 38 people served as justification for a large-scale and rapid eviction program. The municipality commissioned Geo-Rio to provide a risk assessment and mapping report that designated 21,000 houses in 117 communities at risk of landslides and needed clearance (Mendes Barbosa & Walker, 2020; Burgos, 2016). This event had also led to the installation of warning systems throughout favelas in the city, among them Rocinha, a project led by Rio de Janeiro Municipal Civil Defense (Abelheira et al., 2019).

In Rocinha, Geo-Rio carried out three interventions to contain slopes, In 1985, 1992, and 2010. Its 2010 reports were partially implemented in a 2013 project for slope stabilization, drainage, and environmental recovery downstream of Rua Maria do Carmo. It also classified around 200 houses in Rocinha as at-risk and needing clearance (NINJA, 2019), among them the entire Laboriaux street (Burgos, 2016).

Unidade de Polícia Pacificadora (UPP), launched in 2008, is Rio de Janeiro state's most extensive public security program to date, deploying Police Pacification Units (UPPs) in favelas. UPP

arrived in Rocinha in 2011. (Burgos, 2016). PAC and the UPP represent by far the most significant and expensive interventions in the history of Rio's favelas and Rocinha (ibid.).

Minha Casa Minha Vida (MCMV), Brazil's federal social housing program that was launched in 2009, played a unique role in Rio de Janeiro's vast removal of favela residents and the creation of a more socio-spatially polarized city (Burgos, 2016). Managed by the Federal Ministry of Cities and funded mainly by Brazil's largest state bank, Caixa Econômica Federal (ibid.), the program had delivered more than four million dwellings across the country in the past decade (Martins and Saavedra Farias, 2019). Since 2011 MCMV has increasingly complemented projects that are part of PAC. Though MCMV is not designed to upgrade favelas, its impact on the housing market and its role in inducing relocation programs (Burgos, 2016) make it worth discussing in this context.

Bolsa Família, the social welfare program, presents a conditional cash transfer scheme that allocated approximately R\$ 121.6 billion of the Brazilian federal budget to Brazil's poorest families between 2007 and 2104 (Burgos, 2016). Although the program started in the 1990s, it was greatly expanded in the early 2000s to the scale and scheme it is known for today (Hall, 2008). The program aims to make both short-term and long-term reduction of poverty; short-term by direct cash transfers, and long-term by making the payments conditional upon school attendance and healthcare participation to enhance human capital (ibid.). Such a program aims at reducing socio-economic vulnerability and has the power to enhance the ability of favela residents to invest in more robust construction of their houses.

The reviewed programs showcased several approaches for reducing hazards vulnerability; removal, upgrading, offering alternative housing solutions, and financing mechanisms to reduce socio-economic vulnerability. Wekesa et al. (2011) argue that informal settlement upgrading is one of the few approaches that seem to work. However, apart from the CODESCO scheme in the 1960s and the ATHIS law, which were in-effectively implemented, the other schemes reviewed in this chapter do not focus on private homes but on public spaces and infrastructure. Favela upgrade schemes are also criticized for their inadequate participation (Martins and Saavedra Farias, 2019) and their political

exploitation for declaring risk areas to remove residents (Burgos, 2016; Alvarez & Cardenas, 2019). Conditional cash transfers schemes, therefore, present a different approach to tackle vulnerabilities in focusing primarily on households. Yet, more research will be required in order to understand their impact on investment towards more robust housing construction in informal settlements.

When considering such policy measures, it is vital to consider the public sector capacity and financial means to undertake such projects (Wekesa et al., 2011). Such challenges, however, might be addressed by a partnership between governments, the private sector, and donor agencies (ibid.). However, the collaboration between different levels of government and other actors can also pose a challenge as political interests might differ. A reference to such differences in interest can be found in Osborn's (2012a) discussion on the policies in Rio de Janeiro during the 1960s.

Funding capacity and inter-actor collaboration are not only challenges for public-sector projects; there are numerous community-scale initiatives to reduce vulnerabilities and enhance socioeconomic aspects driven by a range of actors using various financing mechanisms. The following paragraphs will discuss several initiatives that are particularly relevant in the context of reducing vulnerability to hazards.

Community-based initiatives

“The last 20 years have brought many upgrading initiatives driven by community organizations formed by their residents and supported by local governments” (Satterthwaite et al., 2020, 149).

There is an inspiring number of initiatives that tackle education, social rights, waste management, and environmental sustainability in Rio's favelas. Due to the large scale and prime location of Rocinha, it has received particular attention from foreigners and NGOs (Burgos, 2016). Whereas all initiatives have the potential to reduce vulnerabilities to hazards, either directly or indirectly, for the purposes of this study and its focus on the built environment, this chapter will discuss only a few of them; *Rocinha Sem Fronteiras*, *De Olho no Lixo*, and *Favela Verde*.

Rocinha Sem Fronteiras is a community-based activist group operating for over 15 years. Its mission is to promote citizenship and mobilize residents to action through information with monthly

debates on issues relevant to human development and of Rocinha residents, such as sanitation and decent housing, as well as through communication, campaigns, and other collective actions (Rocinha Sem Fronteiras, 2018a; 2018b). With years of activity, the group gained extensive local understanding and legal knowledge and the ability to mobilize residents to action.

De Olho no Lixo: Transforming Waste into Art, Culture, and Education is a program aimed at Integrated Waste Management in favelas; to minimize the impacts of inadequate waste management and stimulate the generation of income from waste (Viva Rio, n.d.a; Viva Rio, n.d.b). The program works in 3 favelas in Rio de Janeiro, among them in Rocinha since 2016, and collaborates with education, art, music, and fashion institutions to promote recycling programs. The program is a result of collaboration between Viva Rio, the Instituto Estadual do Ambiente (INEA), and the Secretaria de Estado do Ambiente (SEA), with support from the Rio de Janeiro State Supermarket Association (Asserj) (Viva Rio, n.d.a). During the Covid19 pandemic, the program expanded to provide risk reduction measures- residents' training about proper sanitation, dissemination of face masks, and sanitation products (Viva Rio, n.d.b).

The Favela Verde organization has been operating in Rocinha since 2013. It carries out socio-environmental projects aimed at urban resilience and sustainability through environmental education, community gardening activities, and more (Kuck, 2017; Carvalho, 2017)

Community-based initiatives have a capacity to address vulnerabilities, building on their understanding of the local context and needs as well as their ability to mobilize the community to action. However, their dynamic nature and small scale pose a dual challenge: the initiative's capacity to gather technical expertise and funding and the government's ability to learn about these local initiatives to engage with them for community development. Initiatives operating at the level between government and communities provide an opportunity to serve as a mediator in resolving these challenges, offering a model for a cross-level multi-stakeholder approach. CatComm, which will be explored further below, is one such initiative.

Third and Private sector work

At a conceptual level, between municipalities or governments to local communities, there is a wide range of NGOs, nonprofits, universities, and even companies of the private sector, who are involved in developing communities and reducing their vulnerabilities in informal settlements. Such organizations provide two significant contributions to the development efforts; they can gather and pass knowledge and mediate and facilitate collaboration between the public sector to local communities, and they can also bring technical expertise and experience from various fields that might not exist in the communities. In that way, they may operate as the executive mechanism of larger-scale policies or programs. It is also important to acknowledge multi-national and international organizations' role in funding, facilitating collaboration, and sharing technical expertise when considering the third sector, though this chapter will not examine such organizations.

The following paragraphs will discuss the Rio de Janeiro-based initiative *CatComm* and the Sao Paulo-based platforms *ATHIS* and *Vivenda* for their role in facilitating networks and knowledge accumulation, as well as initiatives from the private and third sector that address housing development in favelas; *Arquitetura na Periferia* and *Fave.Lar*.

Catalytic Communities (CatComm) is a Rio de Janeiro-based NGO that was founded in 2000 to assist favela organizers in their communities (Williamson, 2021). The NGO has a four-fold strategy: (1) changing favelas narrative; deepening the understanding and battle stigmatization, with the lead journalism project established in 2010 *Rio on Watch*. (2) Enhance a network of sustainable models for community development through the *Sustainable Favela Network* initiative. (3) Design and implement a comprehensive land titling strategy through the *Favela Community Land Trusts* model. (4) crowdsource data to ensure informed, accurate, and practical policy responses, with the lead project 'favela unified' the dashboard for Covid19 (ibid.). Under the umbrella of Catcomm, grassroots initiatives and local communities can access knowledge, get training and be part of a network of initiatives to support their efforts to develop and grow their community.

Assistência Técnica de Habitação de Interesse Social (ATHIS), a Sao Paulo-based collaborative platform, was created in 2016 by the non-profit Peabiru Trabalhos Comunitários e Ambientais, with funding from the Council of Architecture and Urbanism (CAU/SP), built upon decades of organization of technical assistance entities and the legislation for technical assistance in 2008. The platform aims to bring together professionals, activists, academia, and others who are involved in housing production processes for the low-income population to exchange experiences and build a foundation for action that facilitate the provision of technical assistance for low-income housing and supporting the fight for their right to the city (ATHIS, n.d.). Their practical activities include providing workshops and building a knowledge base about initiatives and practices in the field.

Vivenda was founded in 2013 in Sao Paulo with the objective to revolutionize the housing reform sector for low-income families. As of 2021, Vivenda changed its business model from performing the renovation work to operating as a platform to structure the housing reforms sector on a larger scale (Vivenda, n.d.a). The new model has three pillars: (1) Instituto Vivenda - an "action tank" to promote the construction and implementation of initiatives in the field, as well as to bring together different actors; government, companies, civil society, and institutions research, to develop solutions in the housing market (Vivenda, n.d.b). (2) Nova Vivenda - a platform to facilitate housing reforms by connecting people interested in renovation to service providers. The working model is an 'all in one place'; design, materials, and labor are all part of the contract, including house visits and flexible payment methods to address the target population (Vivenda, n.d.c). (3) Vivenda Play - an accelerator for social entrepreneurs that certify new businesses in the field (Vivenda, n.d.a).

Arquitetura na Periferia (AnP) is a technical assistance program, a non-profit that teaches design and construction planning practices and techniques and provides micro-financing for women from the periphery to renovate and improve their homes. The project originated with the objective to develop a method to improve housing quality through work with a public accustomed to self-producing its own housing without technical assistance or training. People building their homes without knowledge result in houses with scarce or unutilized resources, structural problems, excessive

humidity, lack of lighting and ventilation, or even the absence of a bathroom (AnP, n.d.). The program operates in 5 communities in Belo Horizonte, and to this day, performed more than 200 workshops and more than 60 training that benefited the processes of more than 30 renovations of houses (AnP, n.d.). The availability of financial resources is one of AnP's main challenges. In the lack of formal public programs to finance technical assistance (ATHIS), AnP relies on philanthropic funds, donation campaigns, social projects support, workshops, and partnerships with companies (Mendoca & Borel, 2019).

Fave.Lar is a Rio de Janeiro-based social business that was founded in 2015. It aims to provide services to all or all favelas and peripheral populations. It connects qualified labor to those who need to build or renovate, offering technical assistance and providing knowledge and training to professionals who work or intend to work with ATHIS. Similar to the Vivenda model, the Fave.Lar model offers materials and construction workers and aims to establish a micro-financing mechanism, though these are not mandatory services (Fave.Lar, n.d.)

The third and private sector presents several models that focus on the self-built housing process by facilitating collaboration, providing reform services, or guiding the design and build process. At the level between government and communities, such initiatives provide an opportunity not only to accumulate knowledge but also to facilitate horizontal and vertical collaboration. Smaller-scale initiatives provide professional expertise that does not exist at a community level and is not provided at a public sector level.

The private sector provides a business model that can overcome the third sector's funding challenges; nonetheless, there are two significant distinctions between the Vivenda and the AnP model; while Vivenda and Fave.Lar focus on home reforms, which are mainly interiors, AnP work also involves expansions and constructions. Furthermore, AnP work aims to provide tools rather than a product to empower participants' capacity. These two distinctions are particularly important when considering the local context and level of development of favelas; a model that works in less urbanized favelas on the outskirts of cities may not work in highly consolidated favelas in city centers.

Table 2.
Characteristics of Policy Measures and Initiatives to Reduce Vulnerability to Hazards

Title	Years	Scope	Operational Body	Implementation level	Implementation focus	funding
Governmental Policy Measures						
Federal Law for Technical Assistance (ATHIS)	2008	Law, free technical assistance for low-income households	Federal government	Country (largely unimplemented)	Household	
Favela Bairro	1994-2005	Program, favela upgrading	Municipality of Rio de Janeiro	City	Community	IDB and State Government
Acceleration Growth Program (PAC)	2007	Program, favela upgrading	Federal government	Country	Community	Mainly state companies and the private sector
Morar Carioca	2010	Program, favela upgrading	Municipality of Rio de Janeiro	City (largely unimplemented)	Community	Partially federal funding
UPP	2008	Program, security	State government	State	Community	
GEO-RIO - Municipal Geotechnical Institute	1966	Institution, risk assessment, and slope containment	Municipal body	City	City / Community	Municipality
Minha Casa Minha Vida (MCMV)	2009	Program, social housing	Federal government	City	City	Caixa Econômica Federal Bank
Bolsa Família	1990, 2000s	Program, social welfare	Federal Government	Country	Household	Federal government
Community-based initiatives						
Rocinha Sem Fronteiras	~ 1995	Activism, socio-spatial rights	Grassroots Initiative	Community	Community	
De Olho no Lixo	2016	Initiative, waste management	collaboration between Viva Rio, INEA, and SEA	City, several communities	Community	Rio de Janeiro State Supermarket Association (Asserj)
Favela Verde	2013	Initiative, socio-environmental	Community actors in collaboration with professional actors	Community	Community	
Third and Private sector work						
Catalytic Communities (CatComm)	2000	Media and socio-spatial rights	NGO	City	Collaboration between actors and communities	
ATHIS	2016	Improve practices of housing solutions	Platform created by a nonprofit	State, Multi-City	Collaboration between actors and communities for the benefit of household	Grant money
Vivenda	2013	Improve practice + housing solutions	Private sector company	Country, Multi-City	Collaboration between actors and households	Business model
Arquitetura na Periferia (AnP)	2013	Housing solutions	Nonprofit	City	Household	Donations
Fave.Lar	2015	Housing solutions	Private sector company	City	Household	Business model

Note. This table is adapted and synthesized from the examined literature in this chapter.

The reviewed policy measures and initiatives contribution to this study discussion is twofold; accumulating a database of good practices is essential to learn from their “know-how” in order to develop a model. It also allows the identification of gaps and unaddressed issues. Table 2 presents a synthesized summary of the main policy measures and initiatives reviewed in this chapter.

The policy measures and initiatives reviewed reveal that finance and coordination between actors, although critical for obtaining funding, implementing projects, and gaining practical knowledge, is a common challenge at all levels. Though these are highly dependent on government capacity, collaborating with international or multinational bodies poses an opportunity for capacity development and funding. Wekesa et al. (2011) discuss household financing challenges, indicating that financial institutions frequently exclude poor populations due to their lack of collateral assets. To overcome this problem, they offer loan guarantees and social funding models, which are alternatives to microfinancing and flexible payment mechanisms adopted by the studied initiatives. They also propose that the public sector use incentives and legal measures to encourage private sector involvement in housing provision (Ibid.). Although none of the reviewed programs used the latter strategy, it has significant potential to encourage the provision and expansion of more resilient housing.

The ATHIS law, despite its promise, was stated to be ineffectively implemented (CAU/BR, n.d.; ATHIS, n.d.). Table 2 highlights that, of the policy measures and initiatives addressing built-environment, only the third and private sectors manage to address processes occurring at the household level. It might be presumed to be due to the level and scale of their work, which allows them to apply realistic models and address local context and challenges on a household level, as well as their professional skills, which are critical for designing and carrying out such operations. Though a federal law might face challenges in developing a program at a national scale for assisting private construction processes, developing a funding mechanism to support smaller-scale initiatives in doing so would have benefited the cause.

Even programs concentrating on housing production were found not to evaluate or investigate a reform or building project's impact on its neighbors and neighborhood. It could be due to their less urbanized level of development, which may not alert its significance, but as population growth and urbanization processes direct more people to live in favelas, the built environment growth is inevitable, and what does not appear to be a problem today might become so tomorrow.

Martins and Saavedra Farias (2019) describe the two different processes that coincide in Rocinha and favelas in general. While efforts are being made to implement urban upgrading projects that involve large-scale interventions in spatial layout and infrastructure and may result in resident resettlement, houses continue to grow and expand, mostly vertically, representing the favela's primary growth mechanism. This incremental growth exacerbates existing or creates new vulnerabilities; overburdening infrastructures and services, affecting the provision of natural light and ventilation to its surroundings, and more. It is then evident that upgrading measures cannot solely create infrastructures and react to existing vulnerabilities or focus on individual households' living standards, they must also mitigate the creation of vulnerabilities through the process of self-built housing.

2.4. Biases and Literature Limitations

The literature review discussed key aspects related to informal settlements, favelas in particular, and vulnerability to hazards; it established the relations between incremental growth and creation of vulnerabilities to hazards in the theoretical framework, discussed specific characteristics of vulnerability to hazards in the context of urban informality, and reviewed existing policies and programs to address them.

It is acknowledged that using mainly literature written in English while performing a study in the context of non-English speakers might result in bias. This study addresses this by reflecting upon the English literature with both Portuguese one and literature that research the same location and context.

Moreover, primary sources, locally collected in Portuguese, the spoken language in Rocinha, are used to reflect upon the literature review findings.

The scale and timespan of this study, especially when performed during the Covid19 pandemic, limited the extent of this literature review. Additional literature will need to be examined to establish this study's claim in a broader context.

The main gap and limitation of the literature reviewed was the failure to conceptualize the impact of the self-built homes' incremental growth, the growth mechanism of informal settlements, on the creation and exacerbation of vulnerabilities to hazards in these communities, led to the lack of examination of its specific characteristics and the lack of policy measures and programs that address it. It also had led to the limited examination of vulnerability changes over the years or future vulnerabilities related to changes in the built environment. This study will aim to address that by developing a model for a community's risk-sensitive growth focusing on incremental self-built housing.

3. A local analysis of vulnerabilities in Rocinha: fieldwork and survey

The former chapter examined vulnerabilities in informal settlements through scholarly discussions; this chapter will present a local context analysis of the specific vulnerabilities in Rocinha. It will aim to discuss not only vulnerabilities but also interactions and cross effects between them, future impacts of current vulnerabilities, and future vulnerabilities emerging from the process of spatial growth.

This chapter is constructed by four sub-chapters which produce a localized analysis of Rocinha's vulnerability to hazards; Chapter 3.1 presents the primary data collection methods, Chapter 3.2 present and discuss the residents' online questionnaire result, Chapter 3.3 formalizes a local causal map of flood vulnerability, based on the knowledge gain through the fieldwork and the literature review, Chapter 3.4 conclude with a discussion on the implications of the local analysis.

3.1. Research Methods

The main method used in this research is a case study of Rocinha, a favela in Rio de Janeiro, Brazil. In order to get insight and in-depth understanding of houses' incremental growth process and vulnerabilities, the use of primary sources of both quantitative and qualitative nature, collected through two processes, was prioritized; an online questionnaire and fieldwork. Secondary sources examined in the literature review were used to reflect upon the collected data in order to develop a model for risk-sensitive development and establish the research as valuable in a wider context of favelas and urban informality in the global south. Though the focus of this study is on the built environment, other areas were covered by the questionnaire. This was done both in order to verify the relevance of the built environment in the discussion and since, as discussed in the literature review, socio-economic vulnerabilities affect the built environment ones.

The online questionnaire consisted of both qualitative and quantitative methods. It was carried out in Portuguese between September 28 and November 11, 2021, with the findings translated to English and reported in this paper. The questionnaire was set to have a minimum of 60 participants from different areas in Rocinha and different age groups. A template of the questionnaire is presented in Annex A.

The questionnaire was divided into five parts; general information about the participant, assessment of the main vulnerabilities in the community, assessment of the severity of each vulnerability, impact on the house from hazards or development, and general housing information. The general housing information part was optional and was included as the final section of the questionnaire out of sensitivity to the local culture and recognition that respondents may not be eager to disclose this information. Furthermore, the word "challenge" was used in the questionnaire to refer to vulnerability, hazard, and exposure altogether. This was done to tailor the questionnaire for local residents who are unfamiliar with the disaster risk framework and its terminology.

The fieldwork was completed earlier to the formulation of this study yet in the same field of study. It was composed of two main activities, the documentation of six homes in Rocinha, including in-depth interviews with residents, and taking part in a local flood response team performing analysis of disaster impact and recovery actions. These two activities will be used in this study for the formulation of a local causal map of flood vulnerability.

The documentation work consisted of six homes that differ in location, typology, age, and family structure (see Table 1). The documentation was carried out while I was living in Rocinha for over a year and a half, from July 2017 to February 2018 and from December 2018 to July 2019. Each of the six homes was documented for its architectural form, patterns of use, history of development, structural and social challenges, and the decision-making and problem-solving process throughout the development of the self-built home over the years. For the documentation, I used a combination of anthropological and architectural tools such as interviews, oral history, studying old photos and documents, photography, sketching, and architectural drawings. A focus was given to analyzing the form and development of the house, crucial knowledge for understanding the spatial manifestation of the vulnerabilities in order to develop a locally contextualized model for intervention.

Table 3.

Documented Homes General Characteristics

Main Resident Interviewed	Location	Typology	Age of building	No. of Generations	No. of Floors	Other Uses	No. of People Informally Interviewed
Camila Carvalho	Down, central	Building owner	33	2	7.5	Rent, Business	5
Ullie Lopes	Down, central	Building owner	18	3	5	Rent	2
Jose Paiva	Middle, M.C.A	Building owner	26	3	4	Rent, Business	4
Eudes Mello	Middle, M.C.A	Building owner	49	2	2	Rent	1
Dila Oliveira	Down, M.C.A	Apartment, family building	25	1-3	5	Rent, Commerce	1
Dayane Souza	Top	Multi-owners, family building	30	2	3	-	2

Note. M.C.A used to indicate the area of Rocinha in general control of the local mafia (drug gangs) at the time of the fieldwork. Other areas are in general control of the UPP (police).

Table 3. Present the main criteria upon which the documented houses were chosen.

Due to the nature of the studied location, there were many challenges and limitations in the documentation process, such as highly irregular spatial forms, areas controlled by the mafia that cannot be photographed, lack of past documentation/memory, and cultural approach and daily routines that made it difficult to schedule and perform formal interviews. To address these challenges, most of the production of the architectural drawings was performed 'on-site'. It allowed me to re-measure and re-assess issues when needed, but more importantly, make many informal conversations and interviews with the different residents, giving them time to recollect their memory or search for further information from relatives. In the process of data gathering, I used a guideline containing the data I needed to collect and interview questions. I meticulously made notes of all informal conversations. The guideline is presented in Annex B.

In February 2019, heavy rains fell in Rio de Janeiro, resulting in extensive damage to houses, assets and the loss of life of one resident of Rocinha. Following the event, a group of residents, many of them students and local activists, formed a response team to assess the damage and facilitate recovery. As an architect and a resident at the time, I joined the team's response and recovery efforts. My notes from the flood and the response will be used in this study in the formulation of a local causal map of flood vulnerability.

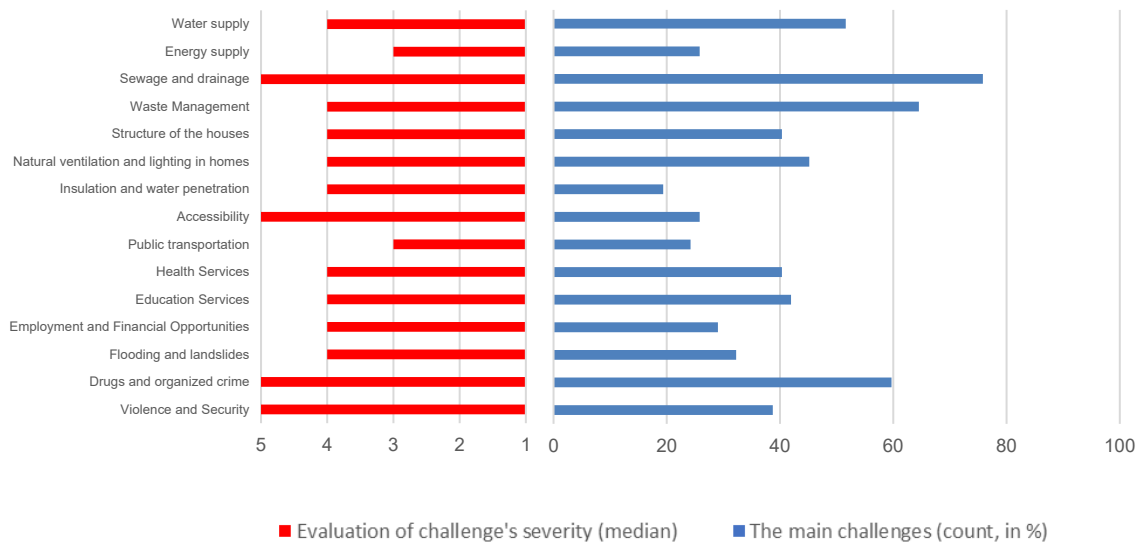
3.2. Residents Questionnaire Analysis

The purpose of the survey was to acquire a local perspective on the most prominent vulnerabilities to hazards and their severity in Rocinha. To tailor the questionnaire for residents who are unfamiliar with the disaster risk framework and its terminology, the word "challenge" was used in the questionnaire to refer to vulnerability, hazard, and exposure altogether.

The butterfly bar chart in Figure 4. presents the residents' perspective of the main challenges in Rocinha (right) and evaluation of their severity (left). This chart allows one to read the information

both vertically and horizontally simultaneously; assess the importance or severity of one challenge in comparison to others, and get a sense of the gap between its importance and its extent. The main challenges were evaluated by counting the responses to each category in a multiple-choice question, while the degree of severity of each challenge was assessed using a Likert item ranging from 1 (not severe) to 5 (very severe). Residents also could add challenges or make a textual comment about them.

Figure 4. Residents' Perspective of the Main Challenges in Rocinha and their Severity



Note. The main challenges (right) were evaluated by counting the responses to each category in a multiple-choice question, while the degree of severity of each challenge (left) was assessed using a Likert item ranging from 1 (not severe) to 5 (very severe).

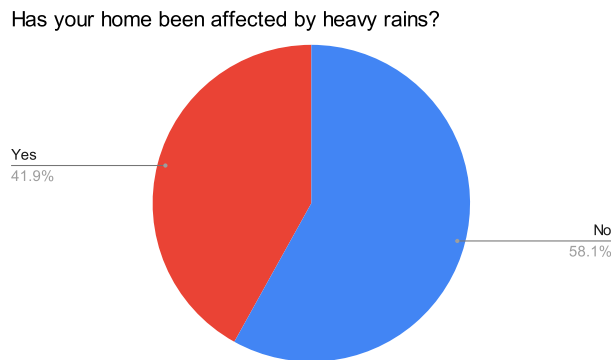
Figure 4. presents that according to residents, the most prominent challenges in Rocinha are sewage and drainage (75.8%), waste management (64.5%), drugs and organized crime (59.7%), and water supply (51.6%). At the 'second level importance', residents reported natural ventilation and light (45.2%), the structure of houses (40.3%), education (41.9%), health (40.3%), and violence and security (38.7%). Sewage, drainage, waste, and water are all common infrastructure vulnerabilities that were discussed in the literature review as common to informal settlements. Drugs and organized

crime are local characteristics of many favelas in Brazil. Though it is not at the focus of this, it is affected by and affects the built environment.

Figure 4. reveals that although there is a partial correlation between the importance and severity of some of the challenges, other challenges, although high in severity, do not appear to be as important in residents' eyes. Sewage and drainage, as well as drugs and organized crime, are not only revealed to be the main challenges, but also their evaluation is very severe. On the other hand, Accessibility was evaluated as very severe (scale 5), but not so important compared to other challenges the residents of Rocinha face. Insulation and water penetration, though selected the least by participants (19.4%) as one of the main challenges, was evaluated high (scale 4) in its severity. Energy supply and public transportation, though widely discussed by scholars as common vulnerabilities in informal settlements, are revealed to be of low importance and also relatively low in severity in the case of Rocinha.

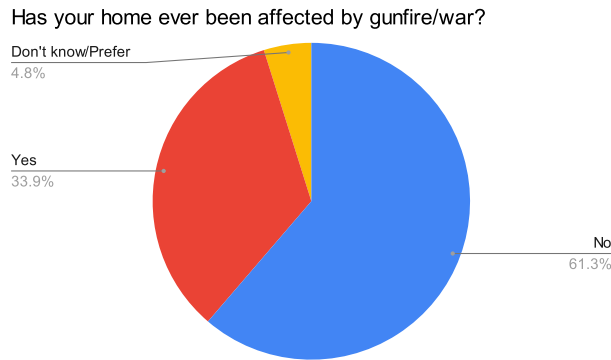
Although insulation and water penetration were selected the least by participants (19.4%) as one of the main challenges, as presented in Figure 5., 41.9% of the residents reported that their house was affected by heavy rains. Among the respondents, residents reported water penetrating through windows and walls as well as additional challenges to dry off the house due to lack of ventilation and high humidity that leads to mold.

Figure 5. Heavy Rains Challenge to Rocinha's Houses



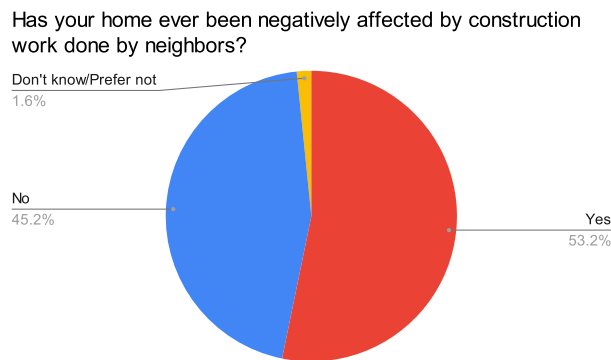
The further effect of drug gangs and low security on the living standards and built environment is evident in Figure 6. where a third of the respondents reported their house being affected by gunfire or war. Though most residents chose not to elaborate on this topic, some shared that bullets entered through their windows.

Figure 6. Security and Drug Gangs Challenge to Rocinha's Houses



The prominent effect of neighboring construction and growth on houses in Rocinha is evident in Figure 7. where 53.2% of respondents reported about it. In textual comments, respondents share that neighboring construction prevents ventilation or natural light and affects the structural strength, causing infiltration problems and cracks in the house structure.

Figure 7. Neighboring Construction and Growth Challenge to Rocinha's Houses



The importance and severity of vulnerability characteristics as the residents of Rocinha perceive them offer insight into the local context and a solid basis for developing a risk-sensitive growth model. Yet, two main limitations must be taken into account;

First, due to this study's small scale and short time, the questionnaire was designed in a very simple way. To truly analyze vulnerabilities and challenges, a more comprehensive examination will have to be performed to identify what level they are happening at. For example, water infrastructure challenges may occur from a city level (water supply by CEDAE, Rio de Janeiro State Company for Water and Sewage, is only limited), at a community level (insufficient or inadequate water infrastructure such as pipes and connectors), in the way houses connected to the main infrastructures (fails at plumbing connections) or within the house itself (lack of water pressure or malfunction of pumps, usage of water tanks). The knowledge gained through the fieldwork was used to shed light on these issues in the model's design.

Second, residents' questionnaires are essential in order to get a local context and prevent biases, but they should not be used as sole input for designing a model. For example, though residents do not perceive insulation and water penetration issues as the main challenges (Figure 4.), water penetration through walls and a lack of ability to adequately dry it out may impact building strength in the long run, resulting in structural failure. Because the effect of water penetration is not yet physically visible, and without professional knowledge, it is difficult for residents to perceive or assess the risk it poses. However, the extent of this vulnerability (Figure 5., and Figure 4. evaluation of challenges severity) deems it essential to address.

Finally, the questionnaire results regarding the effect of neighboring construction on houses (figure 7.) strongly support this study objective to focus on the incremental self-built housing process.

Flooding and landslides were also indicated as challenges on the questionnaire. While these are not vulnerabilities, they were included to put the study in context. Residents responding to the questionnaire referred to this category as the disaster they caused, though according to the framework definition, they are actually hazards caused by another hazard (heavy rain); floods do not have to result in the loss of life or property. Residents reported flooding and landslides not to be one of the main challenges (32.3%) in comparison to the vulnerabilities that lead to their disastrous outcomes. These responses reflect the frequency of events and their proportional impact, as such

events occur once every year or two years and do not result in losses in the entire community, whereas vulnerabilities to hazards, such as a lack of infrastructure and services, or a socioeconomic situation, affect residents' living standards daily. De Sherbinin et al. (2007) or Williams et al. (2019) researches may be used to argue that due to climate change, these events will become more disastrous in the future, but instead, this study argues that these findings corroborate its earlier claim that disaster risk measurements should focus on reducing vulnerabilities. The focus on reducing vulnerabilities to hazards offers two gains: a reduction in disaster risk and a reduction in vulnerabilities that impair residents' daily living standards. Here the term chronic stresses, discussed in the resilience framework in chapter 2.1, might be of better use than vulnerabilities to hazards for representing their concept.

The next chapter will outline a causal map of heavy rains vulnerability in order to describe how the different vulnerabilities interact and affect how a disaster unfolds. The causal map will be the basis for the model developed in this study.

3.3. A Causal Map of Heavy Rains Vulnerability

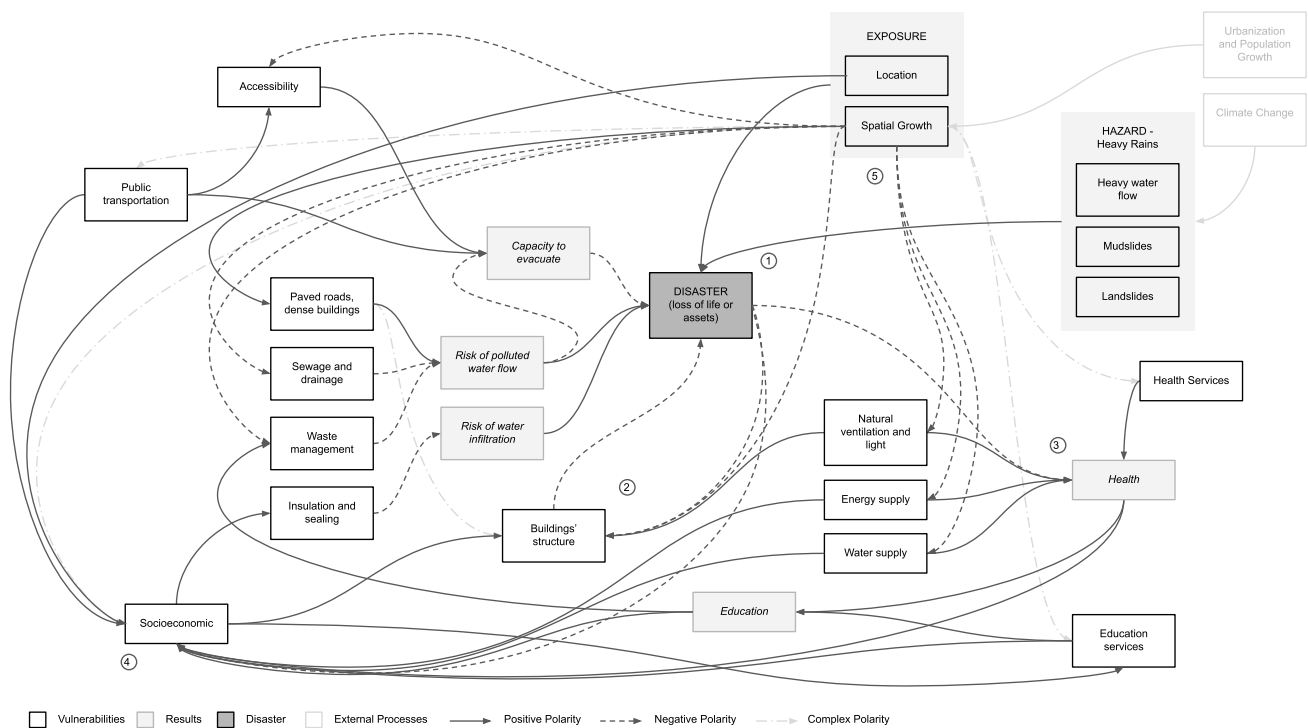
The causal map in Figure 8. presented in this chapter was constructed using knowledge gained through fieldwork and literature review. Two significant disaster risks were identified in Rocinha: the impact of heavy rains and the outcome of drug gang conflicts; because this study is premised on the built environment, the next chapters will focus on the heavy rains disaster. The causal map identifies the variables of importance that underpin or drive the community's vulnerability to heavy rains and the causal linkages between them, which are represented by arrows. The arrow line style conveys the nature of the relationships, with solid lines expressing positive polarity/correlation (if one variable rise, the other rises, and vice versa), dotted lines expressing negative polarity/correlation (if one variable rises, the other falls, and vice versa), and a dash-dotted

line expressing unknown or complex correlation with both polarities. Additional text boxes of 'intermediary results' were added to the map to increase its readability.

The causal map's framework includes the components of risk and their interactions in detail, whereas drivers of these components are regarded as exogenous to the model. It is acknowledged that a set of political entities and relations creates various interventions in the model in the form of political pressure, policy measures, and a wide range of private and third sector initiatives. These were partially discussed in literature review chapter 2.3. and will only be outlined in a conceptual way in figure 8. Moreover, as the focus of this study is on the built environment, socio-economic vulnerabilities were outlined in a conceptual way only.

Figure 8.

Causal Map of Rocinha's Community Vulnerability to Heavy Rains



The causal map (Figure 8.) represents the role of the main vulnerabilities; infrastructure and services, structure, and socio-economic, as well as other risk components, in how a rain-related

disaster unfolds (1). While some of the vulnerabilities, such as paved roads and dense buildings, lack of sewage and drainage, lack of waste management, and inadequate insulation and sealing as well as structure of houses, directly affect the outcome of disaster, other vulnerabilities indirectly affect it. Such effects may be found in the low socio-economic level that prevents residents from investing in building resilient houses, as was discussed in the literature review, or in the lack of education for waste management within the community that results in garbage clogging the main drainage lines, as was reported by residents in the questionnaire.



Figure 10. *Landslide disaster in Rocinha (left) (Reis, 2019).*

Figure 9. *Dampness and Mold in a House, Rocinha (right) (Reis, 2019)*

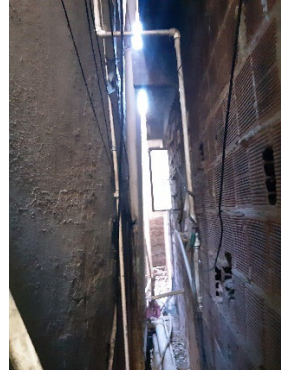


Figure 11. *Typical Structure and Infrastructures Vulnerabilities in Rocinha.*

Open sewerage (left), lack of accessibility and vulnerable infrastructure connections (middle left), lack of exterior sealing and provision of ventilation and natural light (middle right), and vulnerable, and partially self-made connections to power sources (right) (Reis, 2018)

Yet, a heavy rain disaster does not end with the flooding of houses, mudslides, or landslides that cause loss of assets, houses, and lives. The following paragraphs will highlight three additional substantial casualties' relations presented by this map.

First, houses flooded by water or mud polluted by overflowed sewage, coupled by lack of natural ventilation and with no knowledge of how to attend to them properly after such an event, are prone to stay wet and develop bacteria and mold. This could lead to additional respiratory health issues (3), as indicated in the literature review, and compromise building structural strength (2), leading to 'delayed disasters' sometimes years after the event. It also further affects structural and socio-economic vulnerabilities, affecting living standards and the ability to withstand a further disaster.

Second, loss of assets or negative impact on health and education also increases socio-economic vulnerability (4), representing how "disasters threaten development" (UNDRR, n.d.) and further increasing many of the vulnerabilities to future disasters.

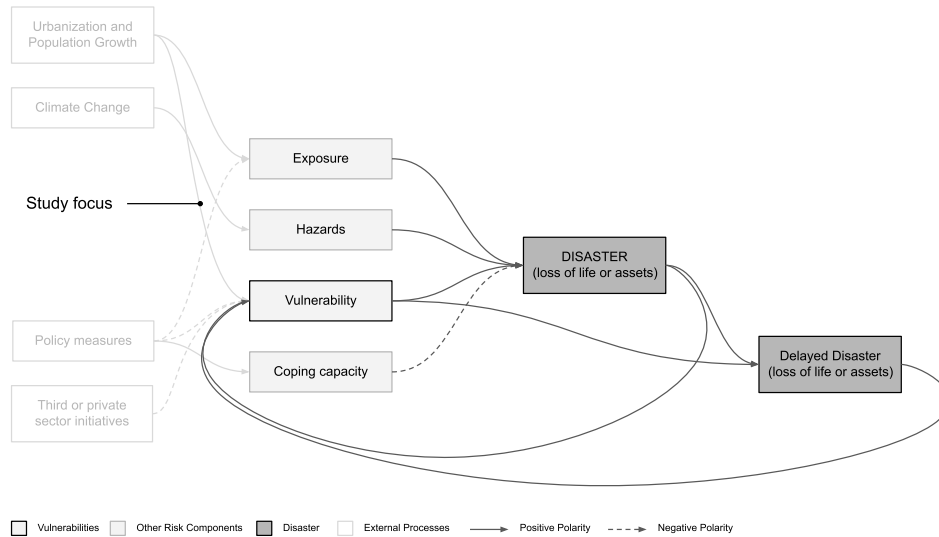
Third, the literature analysis revealed that urbanization and population growth result in the spatial growth of informal settlements, which places additional pressure on land, infrastructure, and services. Since these processes are continuous, the increasing vulnerability of infrastructures, structures, and exposure to dangers is exacerbated continuously (5). In this sense, the causal map does not provide a static image; even if no actions are taken, or no hazard occurs, the vulnerability to hazards is constantly increasing. Williams et al. (2019) present evidence that climate change causes an increase in the number of hazardous events and analyze future vulnerabilities resulting from that increase. The causal map (Figure 8.) offers a tool to examine both external processes' effects on current and future vulnerabilities to hazards.

Figure 12. presents a simplified illustration of the main casualties that emerged from components exogenous to the model; while urbanization and population growth constantly increasing exposure and vulnerability and climate change constantly increasing hazards, policy measures and private and third sector initiatives mainly react to the situation reducing exposure (resettlements schemes) and vulnerabilities (mainly favela upgrades and social welfare projects). Since favelas'

growth mechanism is incremental growth of self-built houses, the model developed in this study will aim to intervene in the growth process itself, preventing the creation and exacerbation of vulnerabilities rather than reacting to the vulnerabilities created by it.

Figure 12.

Rocinha's Casualties Main Concepts and Exogenous Components.



3.4. Discussion on the Local Analysis

The resident's questionnaire results presented in chapter 3.2 offer insight into the most prominent vulnerabilities to hazards and their severity in Rocinha. The causal map constructed in chapter 3.3 discusses the main vulnerabilities and other components of risk that drive the community vulnerability to heavy rains and the causal linkages between them. Acquiring a local picture of the main vulnerabilities, their severity, interactions, and drivers, based on both primary and secondary sources, provides a solid basis for developing a risk-sensitive growth model in the following chapter.

While the causal map (Figure 8.) only shows a partial picture as it only shows the main vulnerabilities and relationships in the context of heavy rains hazards, it already presents a complex picture of vulnerability relationships that relates to many of the issues raised in the literature review and therefore can provide a foundation for the model development. Though the map does not

illustrate the level of impact of each component, it does show the most essential ones. During the model's development, the components will be prioritized based on their impact potential and their feasibility within the model framework.

The impact of incremental spatial growth, led by self-built housing, on the creation and exacerbation of various vulnerabilities to hazards, both structural and infrastructural, was articulated in the causal map (Figure 8.) based on literature review, knowledge gained through fieldwork, and residents' answers (Figure 7.) to the questionnaire. Even though existing initiatives that were reviewed in chapter 2.3. (Vivenda, Arquitetura na Periferia, Favelar) aim at enhancing the process of incremental self-built housing, they primarily address the vulnerabilities within the house borders (such as structural strength, ventilation, and natural light). It will be this study challenge to address the construction of vulnerability beyond the house border via the incremental self-built housing mechanism, such as infrastructural vulnerabilities and impact on neighboring buildings, as defined in the causal map.

4. A Model for Risk-Sensitive Growth in Rocinha

4.1. Model introduction

Earlier chapters established the incremental growth of self-built houses as urban informality's growth mechanism and a prominent urban development paradigm. They also discussed how while policy measures and programs address existing vulnerabilities to hazards in informal settlements, houses processes of growth continue to exacerbate existing vulnerabilities to hazards and introduce new ones. The problem can be conceptualized as follows: every additional floor or even a room constructed in a favela has the potential to increase or reduce the vulnerability of the entire community, and existing policies and programs do not address that.

This chapter proposes a model to improve access to better standards and techniques of incremental housing construction, expansion, and renovation, in order to increase houses' resilience

to hazards and reduce their negative impact on neighboring buildings and on the community's vulnerability to hazards in Rocinha, Rio de Janeiro.

The model aims to contribute to the increase of living standards and resilience to disasters in the Rocinha community; it does not aim to drastically reduce existing vulnerabilities to hazards but to prevent their exacerbation and the emergence of new vulnerabilities. It complements existing policies and programs by proposing a way to address a gap identified in them.

The model was built based on knowledge learned in this study. Drawing on the literature review findings, the model offers a multi-stakeholder approach. It proposes the third or private sector as the lead actor since they were revealed to be most efficient in operating at the household level. Governments, international organizations, and educational institutions proposed as supporters providing financial and capacity support, challenges identified for actors operating at the household level. Collaboration with local initiatives and community actors is also proposed to enhance community engagement and awareness.

Two target groups were identified for the model; First, the residents who initiate expansions and renovations of their houses according to their household needs and financial means. They are the heart of the self-built incremental housing process. Their awareness of vulnerabilities, technical capacity (since the houses are 'planned' and sometimes even built by them), and financial means significantly influence the house's level of resilience and its impact on the community. The second target group is the 'pedreiros' working inside the community. 'Pedreiro' is the Brazilian-Portuguese word for mason, but in the local context, the term refers to the person who performs the architectural planning, engineering, and construction. As many residents of more consolidated favelas contract pedreiros to undertake work on their houses, the pedreiros understanding of the local vulnerabilities and technical capacities to address them is imperative to reducing vulnerabilities to hazards through the building process.

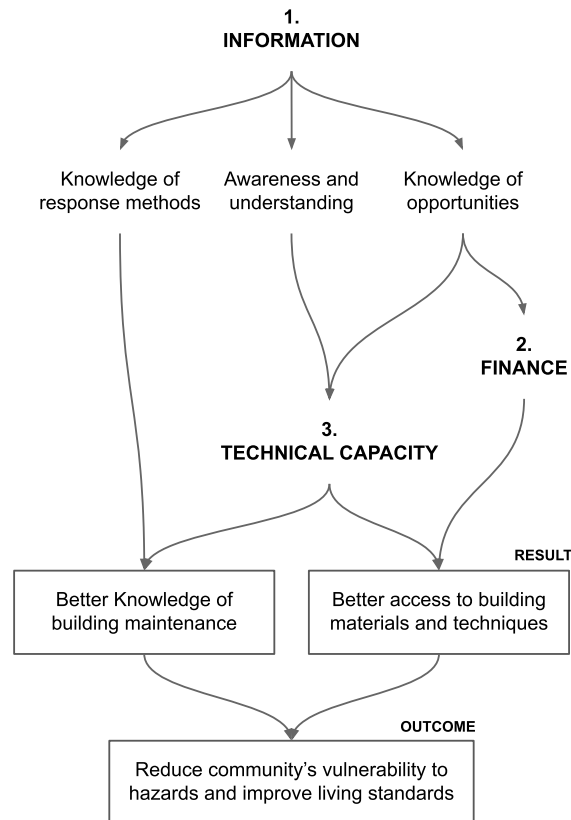
Three lines of action were formulated for the model based on the literature review and fieldwork; information, financing, and technical capacity. These lines of action offer a general

framework that can be adapted to different favelas and even diverse settings of informal settlements. The model's focus on specific vulnerabilities and the activities were constructed according to the local analysis presented in Chapter 3. The following chapter will elaborate on the three lines of action.

4.2. Three Lines of Action

The model proposed in this study is composed of three lines of action; (1) Information - to raise awareness and understanding of vulnerabilities to hazards and improve capacity. Without understanding vulnerabilities, they will not be addressed. (2) Financing- to facilitate access to more robust building materials and techniques, and by that allowing access to more resilient housing. (3) Technical capacity- to improve building design and techniques to reduce vulnerabilities to hazards. Figure 13. illustrates the three lines of action in the model scope.

Figure 13. *The Three Lines of Action of the Model for Risk-Sensitive Growth in Rocinha.*



The three lines of action complement one another and are designed with specific activities to address both target groups. All three lines of action and two target groups are essential for the model's success; for example, improving pedreiros technical capacity without residents having the financial means to contract them will not yield the wanted results. Yet, upon need, the first line of action, information, can be designed and implemented as an independent project or as an earlier phase.

Line of Action 1. Information.

The first step in addressing a problem is to identify and understand it. The resident's questionnaire in chapter 3.2 revealed that residents do not perceive, for example, the potential impact of water infiltration on residents' health and the structural strength of buildings. The existing risk of respiratory health issues and building collapse can be decreased with better preparation and response during times of heavy rains, and it can also be mitigated during the construction process. However, residents need to be aware of the risk and know how to address it. Hence, the model's first line of action focuses on information, aiming to increase awareness and understanding of local vulnerabilities to hazards.

A campaign about preparedness, response, and opportunities for financing and building better can be a powerful tool to achieve awareness and understanding of local vulnerabilities to hazards. In the local context of Rocinha, such a campaign may utilize social media residents' groups, distribute flyers in local hardware stores where many residents and pedreiros go for daily needs or arrange meetings with activist groups such as Rocinha Sem Fronteiras. The last one is also an opportunity to discuss collective responsibility, which may be too delicate to discuss through social media or flyers. Since impacts of private construction in a favela have implications beyond its site and affect the entire favela, there is a need to discuss the collective responsibility of individual actions within the community. Yet, meeting with local groups pose a risk of forming 'elite groups' within the community that solely benefit from the program or acquire a position of power, and therefore it should be done

consciously. Since pedreiros in Rocinha are typically community residents, the campaign can target both residents and pedreiros simultaneously.

The interviews with residents and flash-flood response activities during the fieldwork highlighted the need to address a few specifics in a campaign. Response and recovery measures should include disinfection and ventilation of houses after they have been flooded with polluted water or mud in order to properly 'dry-off' the structure. It is an important measure that is relatively simple to implement to prevent future impacts on health and building structural strength. Informing residents of existing architectural consultation or financing opportunities can go a long way for building better. During interviews, few residents raised the need to get consultation for expanding their houses, while none was aware of existing initiatives, such as Fave.Lar that might offer such consulting. At the scope of the proposed model, informing the residents of opportunities in the model's other lines of action in the campaign will be imperative for its success. Warmness - A shared program for awareness and education about waste management, in collaboration with the local initiative De Olho no Lixo, may also offer an efficient way to raise awareness to waste management challenges and propose methods for household waste management that will relieve some of the pressure on the community level infrastructures.

Line of Action 2. Finance.

Low economic capabilities impact the ability of residents to invest in structural mitigation measures, prepare adequately for hazards, or bounce back in case of disaster. Facilitating access to better materials and professionals by offering financial opportunities or reducing construction costs is essential in a household-based model.

However, funds are not only a challenge at the household level; a review of the literature indicated that NGOs struggle with financing, business ventures face difficulties offering micro-finance, and even at the government level, programs and policy measures frequently lack financial resources. Hence, the focus on financing as a second line of action should examine diverse activities to mitigate the challenges.

Because each place has a unique socio-economic and political condition, the initial activity should be financing mapping. It will allow outlining financing challenges and opportunities unique to the context. The mapping should be conducted implementing participation approaches to avoid biases and get an accurate map.

At a household level, three financing mechanisms can be constructed, according to the findings of the financing mapping. The first is an indirect one, improving socio-economic capabilities through education and provision of labor opportunities, or alternatively, through social welfare programs, such as Bolsa Familia that was discussed in chapter 2.3., will improve the household's economic capabilities and indirectly result in better access to building materials and techniques. This path already exists and can be enhanced. Apart from the state cash transfer program, there are currently several NGOs and community centers working within rocinha with the objective to provide better labor opportunities through education; they could be complemented by programs for capacity development and integration into the labor market. According to the government's financial capacity, such programs can be developed by either the public or third sector.

The two other financing mechanisms directed at the built environment are micro-financing and subsidies or incentives for specific building materials.

Developed by Muhammad Yunus, micro-financing is a common financing mechanism for a population with lower economic capabilities whom financial institutions often excluded due to their lack of collateral assets. However, as AnP work shows, micro-financing might be challenging to provide as it requires funding to establish it. Alternatives can be loan guarantees, social funding, or, as proposed by Vivenda and Fave.Lar, flexible payment mechanisms; these require different funding and organization levels.

The third financing mechanism approaches the challenge from a different direction. It does not aim to increase the economic capacity of households but to reduce the building process costs, making it more affordable. It can be done through policy measures to subsidize specific building materials and components. This mechanism not only allows to reduce building cost but also promote the use of

more sustainable or resilient building components and new technologies to mitigate vulnerabilities. Such components can be structural, to allow for a more robust structure, water-saving elements, to alleviate insufficient water provision, or sanitary, to mitigate health risks within the household, and provide a more stable connection to public infrastructures. It is also an opportunity to introduce household-based innovative technologies for sanitation to mitigate the pressure households put on community-level infrastructures. Though state, city-wide subsidies, or other incentives may require considerable investment and are at risk of being misused, utilized differently than intended, or distort the market. To offer a similar approach on a smaller scale and with less risk and financial means, third or private sector initiatives can collaborate with big companies to offer discounted materials or seek funding and subsidies for the materials themselves.

All three financing mechanisms address the residents' target group and can be offered either by the government or by private or third sector initiatives. In the local context of Rio de Janeiro, where state and local governments lack financial capacity, these mechanisms can be offered and managed by a city-level or community-level initiative. Since financing is a challenge at the initiative level as well, they will still require governmental, international organization, or donor funding. Brazil's scheme for participatory budgeting can offer a way for acquiring funds. With no ability to offer micro-financing and subsidies, Vivenda's business model, which offers flexible payment and collaboration with big companies to purchase materials at lower cost, can offer a sustainable alternative.

Line of Action 3. Technical Capacity.

In a study focused on the built environment and the self-built housing process, it is essential to discuss and outline activities to improve building practices in order to increase living standards and reduce vulnerabilities to hazards. The notion of the need for households to be able to receive technical assistance or guidance is highlighted by initiatives such as Arquitetura na Periferia and Vivenda, and backed by the federal law for ATHIS in Brazil (Lei Federal 11.888, 2008). Building on the existing practices, the third line of action will propose three possible activities to improve technical capacity for both target groups; the residents and the pedreiros.

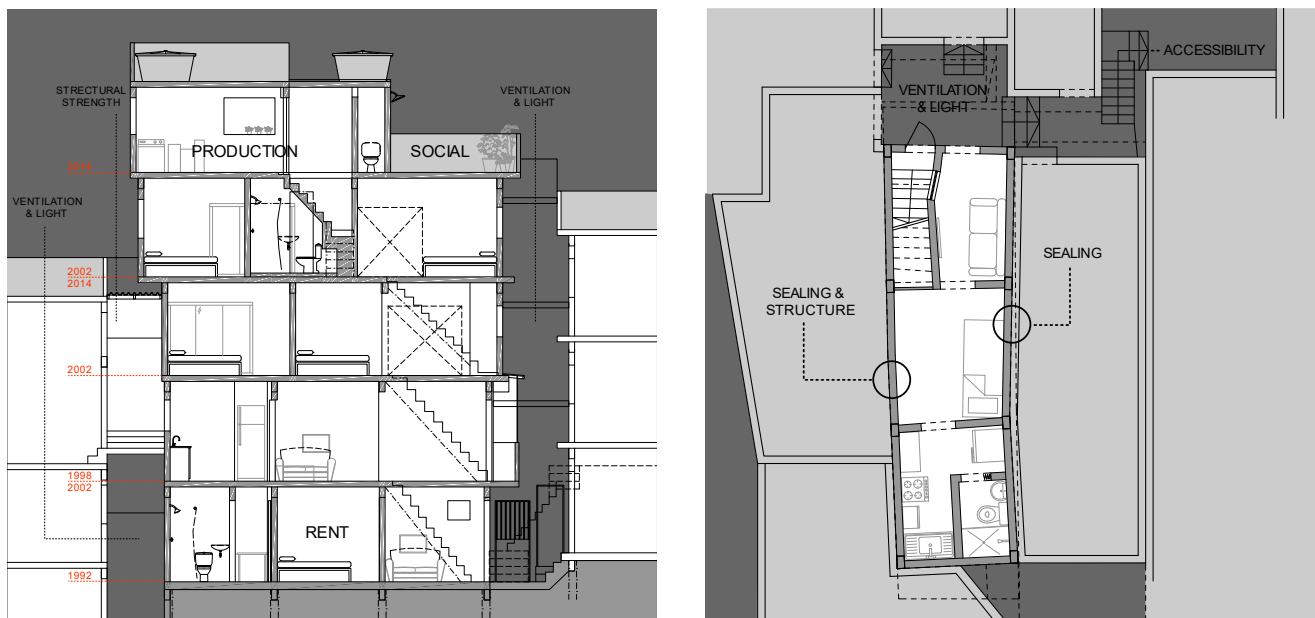
The first proposed activity is training and capacity development workshops for pedreiros. The private or third sector could lead the training, similar to training for professionals offered by Vivenda and the workshops of construction techniques by AnP discussed in the literature review, or the Swiss Humanitarian Aid Competence Center program to train construction professionals to reduce disaster risk in Haiti (Schacher, 2014). This line of action proposes to focus on training local pedreiros within the community. The workshops will benefit from being developed in collaboration with existing initiatives and adapted to the local context.

Such training entails several workshops, one to understand in detail the local building practice, in order to analyze where the practice fails or can be improved, and others to focus on specific practices and techniques that affect the household itself, its neighboring buildings, and the community as a whole. In the local context and level of consolidation and vertical growth of Rocinha, such practices can focus on: (1) Structural Strength, evaluation of current structure issues (subsidence and cracks), how much more the structure can be loaded (how many more floors can be added), how to reinforce the structure and how to prevent effects on nearby structures. (2) Light and Ventilation, learning basic techniques for the provision of natural light and ventilation and the local directions of winds and sun, as well as basic calculations of shadows and obstructions of flows in order to minimize the effect on neighboring buildings. Since numerous socioeconomic factors drive the expansion of houses, this subject may not significantly impact the design decision-making process, but learning about it may enhance practice within the existing process. (3) Insulation and Sealing, understanding the importance and learning techniques for exterior and interior coating in order to reduce water penetration and increase sanitation within the house. Furthermore, examining particular issues and potential solutions between neighboring buildings, such as shared or tightly built walls that produce sealing challenges or water accumulation in narrow gaps. (4) Household Infrastructures, mitigation measures through the location of infrastructures and their connection to the public infrastructures. For example, locating electricity wires high to avoid flooding damage, design of plumbing to avoid clogging or other sanitation problems, and techniques for robust 'plug-in' to the public infrastructures

to reduce risk of leaks or fires that may cause more stress on water provision, health or accessibility challenges, or damage to assets and life within the community. (5) Construction Management, acquiring project management knowledge and pricing to avoid wasteful and costly construction. (6) Information of opportunities for subsidized or discounted building materials or on new technologies as discussed in line of action 2.

Figure 14.

Reported Vulnerabilities in a House in Rocinha.



Note. The architectural drawings of section (left) and ground floor plan (right) of a house in Rocinha were produced by the author during the fieldwork period. The reported building uses and vulnerabilities related to the immediate area and neighbors are indicated in black. Years of development are noted in red lettering on the section.

The second proposed activity is to provide free professional consulting for residents who are interested in the construction, expansion, or renovation of their houses. The consult should be free, following the notion of the ATHIS law, and offer consultation on design, engineering, materials, and, if possible, house visits for assessments. Private or third sector initiatives working at the community or city level were found to be the most effective in managing such activities. The guidelines for consulting should be developed building on existing knowledge or through collaboration with existing

initiatives and adaptation to the local context. Collaboration with nearby universities can benefit both sides; participation of architecture and civil engineering students through volunteering, academic courses, or internships can lower the financial investment required for such operation and allow students to get practical experience or research opportunities. In addition to existing initiatives' objectives, the consult should address cross-effects between different constructions of buildings and have the ability to provide aerial consulting for neighbors facing challenges in their immediate public space.

The third proposed activity is, in a sense, a hybrid of the previous two and therefore offers alternatives to them; it provides consultancy and construction services to residents while also training pedreiros and contracting them as service providers. In a way, it addresses both supply and demand in the local market, based on the Vivenda model and Fave.Lar works in Rio de Janeiro. This activity offers residents a 'one-stop-shop' option for contracting design, labor, and materials all in one place. This option has the potential to overcome funding challenges as it proposes a business model that does not require external funding. It is beneficial for residents as it offers trained pedreiros, lower price quality materials (through wholesaling or collaboration with big companies), and flexible payment or other financing mechanisms. However, it encompasses a risk of excluding local pedreiros from the market. Furthermore, it requires consciousness of tenure issues that might prevent providing construction services and only allow interior renovations. These risks could not be evaluated within the scope of this study, but such an assessment should be performed to determine whether this activity is better suited to the local context.

Table 4. Present a synthesized summary of the Three Lines of Action in the Model for Risk-Sensitive Growth in Rocinha. It highlights the need to act in all three lines of action as they complement one another; enhancing understanding of local vulnerabilities, developing professional knowledge and capacity to address them on the supply side, and improving financial capacity to access better practices on the demand side. The model offers specific activities in the context of Rocinha, and, according to the risks, it offers alternatives in the finance and technical capacity lines of action.

Table 4.
Activities in the Three Lines of Action of the Model for Risk-Sensitive Growth

Activity	Details	Expected Results	Target Group	Operating Body	Risk or Alternatives
Information					
Campaign	campaign about preparedness, response, and opportunities for financing and building better through social media and distribution of flyers in local hardware stores	Increase awareness and understanding of local vulnerabilities to hazards and possible solutions.	Residents and Pedreiros	Private sector, NGOs at community level	Might be too robust to discuss sensitive topics such as collective responsibility.
Residents meetings	Enhance understanding of local challenges and discuss collective responsibility.	Increase understanding of local challenges and possible solutions.	Residents and Pedreiros	Private sector, NGOs at community level	Risk of forming 'elite groups' within the community that solely benefit from the program or acquire a position of power.
Finance					
Financing mapping	outlining financing challenges and opportunities unique to the context.	Decide on the best course of action in this line of action.	Project	Private sector, NGOs	Should be done with the participation of residents to avoid biases and get an accurate map.
Socio-economic welfare programs	Such as education, integration into the labor market or social welfare such as cash transfers.	Improve household economic capacity indirectly resulting in the ability to invest more in construction.	Residents	Government, NGOs	Utilizing existing programs in the local context of the study. Where such programs do not exist, it might be outside the model's scope to develop them.
Micro-Financing	Financing mechanism given directly for construction or renovation purposes.	Facilitating access to better building materials and techniques.	Residents	Private sector, NGOs	Might face challenges of funding. Alternatives can be loan guarantees, social funding, or flexible payment mechanisms.
Subsidies or discounts on building materials	Reduce building costs and promote the use of more sustainable components. Could be done by both government subsidies on specific materials and wholesale or collaboration with big companies to receive discounted materials.	Facilitating access to, and promoting the use of, better building materials and techniques.	Residents	Private sector, NGOs, (optional - Government)	Government subsidies are dependent on financial capacity and might be utilized differently than intended or cause distortion in the market.
Technical Capacity					
Training for pedreiros	Training on specific practices to improve building resilience and reduce its effect on the community focuses on where the local practice fails or can be improved.	Local pedreiros gain better knowledge of design and construction practices.	Pedreiros	Private sector, NGOs	To avoid embedding locally inadequate practices by 'outsiders', must be developed with caution of local context. Might face challenges of funding.
Professional consulting	consultation on design, engineering, materials, and, if possible, house visits for assessments.	Residents get better access to more resilient design and information.	Residents	NGOs, collaboration with local Universities	Must be developed with caution of local context to avoid inadequate service provision. Might face challenges of funding.
'One-stop shop' model	Provide quality design services, qualified labor, low price materials, and flexible payment schemes all in one place.	Enhance both supply and demand access to better building materials and techniques.	Residents and Pedreiros	Private sector	Offer a model to overcome financing challenges as an alternative to the other activities. Risks of excluding local pedreiros and tenure issues that might allow only interior reforms.

Note. This table presents a synthesized summary of the proposed activities in this chapter.

4.3. Limitations and Adaptations of the Model

The model proposed in this study aims to increase houses' resilience to hazards and reduce their negative impact on neighboring buildings and on the community's vulnerability to hazards in Rocinha, Rio de Janeiro. Though the model's objective is not to drastically reduce existing vulnerabilities but to prevent their exacerbation and the emergence of new vulnerabilities, the following paragraphs will highlight two main limitations of the model in doing so.

The proposed lines of action and activities offer a way to directly address houses' vulnerability and their immediate impacts on neighboring buildings, an issue raised as important during interviews and supported in the residents' questionnaire (Figure 7.). However, the model faces challenges reducing the house impact on the community as a whole. This challenge arises since a significant part of the community's vulnerability stems from inadequate public infrastructures (such as drainage and sewage) and service provisions (such as water) that are essential for household operation. The model does manage to address the community level on three aspects: (1) Reducing vulnerability to hazards at the house level and in its immediate surroundings reduces community vulnerability since community vulnerability consists of the vulnerability of its members, which is frequently influenced by its weakest link. (2) Improving houses 'plug in' to the community level infrastructure prevents risks of leaks in water or sewage infrastructures or fires in electricity ones that may cause more stress on water provision, health or accessibility challenges, or damage to assets and life within the community. (3) promoting the use of sustainable components, such as water-saving products (showerheads, faucets, and toilet tanks), rainwater collection tanks, or domestic sewage treatment solutions, can efficiently reduce the pressure households put on infrastructure and, as a result, their vulnerability. However, such solutions should be extensively examined to ensure that they are suitable for the local context and do not introduce additional sanitary risks.

In the objective of further examining the reduction of existing community vulnerabilities to hazards through the house's growth process, this study proposes considering conceptualizing the

government or a private sector stakeholder as a "resident" of operating on its own interest from within the incremental self-built process of growth. What if this actor could rent or buy ground floors of buildings in highly vulnerable focal locations and clear them open to allow flow to reduce sewage and drainage vulnerability while reinforcing the structure against collapsing or even building additional floors to compensate for the one lost? What if this actor could buy a floor or a house to install an areal treatment facility, developing a decentralized sewage treatment system? There are many legal and practical issues and risks to consider in order to assess the feasibility of such a solution, among them land tenure issues, the legal ability of the public sector to hold private property, creating unwanted distortion in housing markets, the impact of intervention and miss-use of the solution to remove population for political reasons or gain political influence through it. For these reasons, this proposed concept is not included in the model proposed in this study. Although further research and thorough analysis are required to develop this concept into a model, the possibilities it opens up offer great promise for reducing existing infrastructure and location vulnerabilities, making it worth mentioning.

Another limitation of the existing model is the financial capacity it requires. Though there is little reliance on public sector financial capacity for that reason, the third sector, which is the prominent stakeholder leading the activities in the proposed model, is also prone to face financing challenges. Even though there are possibilities for funding through the state participatory budgeting or other programs as well as international organizations grants, relying on donors or state funds is not sustainable. The discussed Vivenda model offers an opportunity for an internal financing mechanism, social entrepreneurship, yet, it is limited in its capacity and legal ability to perform all activities proposed in the model. Developing a social entrepreneurship mechanism that supports the achievement of its goal rather than being its primary means to an end may provide a sustainable financing mechanism with the capacity to carry out such a model. It will also benefit from the flexibility to continue utilizing donor funding and grants if the social entrepreneurship mechanism cannot support the model on its own. Such a social entrepreneurship model is implemented by The NGO *Pimpolhos da Grande Rio* Youth Samba School, a cultural heritage, art, and educational program,

and *Carnaval Experience*, a tourism enterprise established to support the NGO financially. It allows the NGO to diversify its funding sources, which are still partially dependent on donor money, making it a more sustainable model with the goal of being entirely independent in the future (Pimpolhos da Grande Rio, 2021; Carnaval Experience, 2021).

The model proposed in this study (Figure 13.) was developed according to the local context of Rocinha, a favela in Rio de Janeiro. However, the literature reviewed in this study establishes the incremental growth of self-built houses as the growth mechanism of urban informality and a prominent urban development paradigm, suggesting the proposed model's relevance in other informal settlements contexts. Though different informal settlements face different hazards (such as heavy rains, earthquakes, hurricanes), the impact of urban growth, structure, infrastructure, and socio-economic vulnerabilities was discussed by scholars as relevant in all contexts.

Building upon the knowledge gained in the literature review, this study presumes the relevancy of the three lines of action suggested in this model. A local analysis will be required in order to adapt the activities to address the local needs, especially in the technical capacity line of action. Adaptation might be needed on the activity level, focus, and design. For example, on the activity level, land tenure vulnerability may deem creating a new activity to address it. In the current model, it was not addressed due to the level of consolidation of Rocinha and the government approach. Proposed activities, such as training for construction professionals or consultancy to residents, may focus on different vulnerabilities according to the local evaluation of their severity. For example, electricity infrastructure and transportation services were analyzed to be of low severity and importance in the case of Rocinah and, for that, were not in the focus of the proposed activities. The design of activities will need to be developed according to local contexts since climate and hazards, as well as building techniques and materials, differ from one place to another. Even within the context of favelas in Rio de Janeiro, different levels of consolidation and distance to urban centers might entail a need for different solutions.

Further analysis and development are required to implement the proposed model, which is outside the scope of this study. Nonetheless, the proposed model provides a solid foundation for future design, adaptation, and implementation.

5. Conclusions

Yvonne Aki-Sawyerr, Mayor of Freetown, Sierra Leone, as she spoke in COP26 (2021), stated that urban informality is “a system that is rooted into micro-enterprises”, emphasizing the opportunity it holds for policies addressing climate adaptation. This study examines the growth process in informal settlements, led by small-scale private construction projects and facilitated by local micro-enterprises. This process presents both challenges and opportunities for building urban resilience.

The overall aim of this study is to advance an understanding of the impact of self-built housing and incremental growth on disaster vulnerability and propose a model for risk-sensitive growth in Rocinha, Rio de Janeiro. Although its limited scope, this study offers three significant contributions:

First, it highlights a gap in academic literature and establishes a theoretical framework to facilitate further research. Through the theoretical framework in chapter 2.1., incremental growth of self-built houses is established as the growth mechanism of urban informality and a prominent urban development paradigm. This growth mechanism is also linked to the exacerbation and the creation of new vulnerabilities to hazards in informal settlements. Existing literature about the characteristics of vulnerability to hazards in informal settlements is examined in chapter 2.2. and existing policy measures and programs that address it are analyzed in chapter 2.3. The reviewed literature revealed that though informal settlements vulnerabilities to hazards are widely discussed in academia for their drivers emerging from their ‘informal’ character; such as location and lack of infrastructures, as well as for their socio-economic challenges, their growth mechanism as a driver of the vulnerability of the entire community is only generally stated. The lack of discussion and examination of it leads to the lack of policy measures and programs that address it in practice.

Second, this study proposes a practical model for risk-sensitive growth in Rocinha, Rio de Janeiro, based on a proposed method for local analysis of vulnerabilities. The analysis is based on primary sources and comprises both residents' input and professional expertise. The model (Figure 13.) aims to complement existing policies and programs by addressing the gap identified in them in the literature review; to improve access to better building standards and techniques of incremental housing in order to improve living standards and prevent the exacerbation and the emergence of new vulnerabilities in Rocinha community, Rio de Janeiro. In order to be practical, the model and analysis were designed in consideration of local governance and financial challenges. The reviewed literature suggests that such an approach to a model does not yet exist; it can only be presumed that without a theoretical framework to conceptualize the growth mechanism as an essential driver of community vulnerability, practices to increase resilience will not perceive it as an urgent. Though further research, detailed design, and impact evaluation, which are outside the scope of this study, will be needed in order to implement such a model, this study proposal can be used as a basis for further design. Furthermore, the discussion in this study may encourage future studies to examine and design other solutions or models.

Third, the academic discussion and practical model suggested in this study have implications that go beyond the context of the Rocinha case study. The literature review suggests the relevance of the theoretical framework and the models' three lines of action in the global context of urban informality. Future research may utilize the knowledge gained through this study to examine and adapt the framework and model to different contexts. Furthermore, current rapid urban growth patterns may imply Rocinha, for its level of consolidation and vertical growth, as a possible future for other favelas in Brazil and even other informal settlements worldwide.

This study falls within the area of urban development, with a focus on the built environment. Due to its limited time-span and size, socio-spatial relations are being only generally examined, yet there is little focus on socio-economic vulnerabilities and cultural aspects. These aspects, such as the operation of drug gangs (mafia) within favelas, or the unique history of colonialism and slavery in

Brazil, which shaped favelas and continue to perpetuate socio-economic inequities, are not less important than the ones discussed in this study and were omitted only due to the study scope. Future studies may further research these aspects from the perspective of a privately led incremental growth process. Nonetheless, this study offers a valuable theoretical framework and practical model that can inform the future work of different actors as practitioners, local initiatives, NGOs, governments, and scholars.

6. References

Abelheira, M. A., Gomes, O. S., de Aguiar, I. S., & da Silva Filho, S. G. R. (2019). Sirenes de alarme para deslizamentos de encostas. *Revista Mosaicos: Estudos em Governança, Sustentabilidade e Inovação*, 1(1), 49-64.

Abunyewah, M., Gajendran, T., & Maund, K. (2018). Profiling informal settlements for disaster risks. *Procedia engineering*, 212, 238-245.

Aki-Sawyer, Y. (2021, November 2) urban informality and inequality: a call for global climate justice [hybrid conference speaker], *UN Climate Change Conference UK2021 (COP26)*.

https://www.youtube.com/watch?v=iz5XiNVI-ig&ab_channel=COP26

Alvarez, M. K., & Cardenas, K. (2019). Evicting slums, 'building back better': Resiliency revanchism and disaster risk management in Manila. *International Journal of Urban and Regional Research*, 43(2), 227-249.

AnP. (n.d.). Arquitetura na Periferia. *Arquitetura na Periferia (AnP)*. Retrieved 17.11.2021 from <https://arquiteturanaperiferia.org.br/>

ATHIS. (n.d.). Sobre [About]. *Assistência Técnica de Habitação de Interesse Social (ATHIS)*. Retrieved 17.11.2021 from <https://www.athis.org.br/sobre/>

Bittencourt, B. K., Cannabrava, M. P., Del Rosario, T. K., Hamilton, M. C., Kampmann, M. E., McGrath, J. T., ... & Lambert, J. H. (2013, April). Evaluating preparedness and resilience initiatives for distressed populations vulnerable to disasters in Rio de Janeiro, Brazil. In *2013 IEEE Systems and Information Engineering Design Symposium* (pp. 58-63). IEEE.

Borel, M. B. M. (2020). *Políticas públicas de assessoria técnica em arquitetura e urbanismo: práticas na direção da autonomia*. [Postgraduate diss., Federal University of Minas Gerais].

Burgos, M. D. (2016). *Development, security and displacement: An ethnographic case study of Rocinha and other key favelas in Rio de Janeiro* [Doctoral dissertation, City University of New York].

Carnaval Experience. (2021). *Carnaval Experience: Social Entrepreneurship*. Internal Document.

Carvalho, F. (2017, November 3). Favela Verde conscientiza Laboriaux sobre preservação ambiental na Rocinha. *Voz das Comunidades*. <https://www.vozdascomunidades.com.br/geral/favela-verde-conscientiza-laboriaux-sobre-preservacao-ambiental-na-rocinha/>

CatComm (n.d.). Primary Housing and Property Laws in Brazil – Rio de Janeiro's Favelas. *CatComm Catalistic Communities*. Retrieved 14.11.2021 from <https://catcomm.org/law-housing/>

CAU/BR. (n.d.). Assistência Técnica para Habitação de Interesse Social. *CAU/BR Conselho de Arquitetura e Urbanismo do Brasil*. Retrieved 17.11.2021 from <https://www.caubr.gov.br/athis-2/>

Cavalcanti, C. A. (2016). How Does Work Shape Informal Cities? The Critical Design of Cities and Housing in Brazilian Slums. *The Plan Journal*, 1(2), 319-333.

CRED, UNDRR. (2020). Human Cost of Disasters. An Overview of the last 20 years: 2000–2019. *CRED, UNDRR, Geneva*.

De Sherbinin, A., Schiller, A., & Pulsipher, A. (2007). The vulnerability of global cities to climate hazards. *Environment and urbanization*, 19(1), 39-64.

Dos Santos, M. C. R. (2007). *Of shacks, houses, and fortresses: an ethnography of favela consolidation in Rio de Janeiro*. [Ph.D. diss., University of Chicago]. UMI Number: 3262292

Dovey, K., & King, R. (2011). Forms of informality: Morphology and visibility of informal settlements. *Built Environment*, 37(1), 11-29.

Fahlberg, A., Vicino, T. J., Fernandes, R., & Potiguara, V. (2020). Confronting chronic shocks: Social resilience in Rio de Janeiro's poor neighborhoods. *Cities*, 99, 102623.

Fave.Lar. (n.d.). Transforme o Sonho de Construir ou Reformar Sua Casa em Realidade: Engenharia e Arquitetura ao Seu Alcance. *Fave.Lar*. Retrieved 17.11.2021 from <https://www.favelar.com.br/>

Gencer, E. A. (2013). *The interplay between urban development, vulnerability, and risk management: A case study of the Istanbul metropolitan area* (Vol. 7). Springer Science & Business Media.

Gencer, E. (2017). *How To Make Cities More Resilient A Handbook For Local Government Leaders*. UN Office for Disaster Risk Reduction.

Hall, A. (2008). Brazil's Bolsa Família: A double-edged sword?. *Development and Change*, 39(5), 799-822.

Handzic, K. (2010). Is legalized land tenure necessary in slum upgrading? Learning from Rio's land tenure policies in the Favela Bairro Program. *Habitat International*, 34 (1), 11-17.

Institute Moreira Salles & Sankofa Museum of the Memory and History of Rocinha (IMS & SM). (n.d.). Timeline - Rocinha's Transformation. *Memória Rocinha*. Retrieved 15.11.2021 from <http://memoriarocinha.com.br/en/linha-do-tempo/>

Jacques, B. P. (2011, April 27). The Aesthetics of the Favela. *BUALA*. <https://www.buala.org/en/city/the-aesthetics-of-the-favela>

Johnson, C., Suri, S. N., & Lipietz, B. (2020). *Words into Action guidelines: Implementation guide for land use and urban planning*.

Kuck, D. (2017, August 28). Lições de sustentabilidade na Rocinha. *#Colabora*. <https://projetocolabora.com.br/mapa-das-ongs/ong-favela-verde-ensina-criancas-a-cultivarem-horta-na-rocinha/>

Lara, F.L. (2009). Chapter 2: The Form of the Informal: Investigating Brazilian Self-Built Housing Solutions. In F. Hernández, P. Kellett & L. K. Allen (Eds.), *Rethinking the Informal City: Critical Perspectives from Latin America* (pp. 23-38). Berghahn Books.

Lei Federal 11.888 2008 (Federal) (Brazil).

Magalhaes, F., & Rojas, E. (2007). Facing the challenges of informal settlements in urban centers: The re-urbanization of Manaus, Brazil. *Inter-American Development Bank*.

Martins, A. N., & Saavedra Farias, J. (2019). Inclusive sustainability within favela upgrading and incremental housing: The case of Rocinha in Rio de Janeiro. *Sustainable Development*, 27(2), 205-213.

Mendes Barbosa, L., & Walker, G. (2020). Epistemic injustice, risk mapping and climatic events: analysing epistemic resistance in the context of favela removal in Rio de Janeiro. *Geographica Helvetica*, 75(4), 381-391.

McCann, B. (2006). The Political Evolution of Rio de Janeiro's Favelas. *Latin American Research Review*, 41(3), 149–163. www.jstor.org/stable/3874692

Mendoca, C. G. (2014). *Arquitetura na Periferia: uma experiência de assessoria técnica para grupos de mulheres* [Doctoral diss., Federal University of Minas Gerais].

Mendoca, C. G. & Borel, M. B. M. (2019). Arquitetura na Periferia. In P. Oliveira, L. Ferreira & V. Iacovini (Eds.). *Dimensões do Intervir em Favelas: desafios e perspectivas* (pp. 165-172). Peabiru TCA.

NINJA. (2019, July 16). Despejo ilegal na Rocinha: Prefeitura do Rio aproveita tragédia para desabrigar famílias. *NINJA*. <https://midianinja.org/news/despejo-ilegal-na-rocinha-prefeitura-do-rio-aproveita-tragedia-para-desabrigar-familias/>

O'Hare, G., & Barke, M. (2002). The favelas of Rio de Janeiro: A temporal and spatial analysis. *GeoJournal*, 56(3), 225-240.

Osborn, C. (2012a, September 27). A History of Favela Upgrades Part I (1897-1988). *RioOnWatch: Community Reporting on Rio*. <https://rioonwatch.org/?p=5295>

Osborn, C. (2012b, November 26). A History of Favela Upgrades Part II: Introducing Favela-Bairro (1988-2008). *RioOnWatch: Community Reporting on Rio*. <https://rioonwatch.org/?p=5931>

Osborn, C. (2013, April 2). A History of Favela Upgrades Part III: Morar Carioca in Vision and Practice (2008 – 2013). *RioOnWatch: Community Reporting on Rio*. <https://rioonwatch.org/?p=8136>

Pimpolhos da Grande Rio. (2021). *Carnival School: Carnival Development, Research and Production Platform Activity Report March 2020 - March 2021*. Internal Document.

Pino, J. C. (1997). Sources on the History of Favelas in Rio de Janeiro. *Latin American Research Review*, 32(3), 111–122.

Pojani, D. (2019). The self-built city: theorizing urban design of informal settlements. *Archnet-IJAR: International Journal of Architectural Research*, 13(2), 294-313.

Resilient Cities Network (n.d.). What is urban resilience?. *Resilient Cities Network*. Retrieved 11.11.2021 from <https://resilientcitiesnetwork.org/what-is-resilience/>

Rocinha Sem Fronteiras. (2018a, April 5). 'No Cosmetic Investments in Rocinha! Health and Sanitation Now!' [PETITION] (C. Pears Trans.) *Rio on Watch: Community Reporting on Rio*. <https://rioonwatch.org/?p=42542>

Rocinha Sem Fronteiras. (2018b, May 30). Reunião: A situação da educação. *Rocinha Sem Fronteiras, Blogger*. http://rocinhasemfronteiras.blogspot.com/?fbclid=IwAR17I_S1WGa7s8IBoHew1yo3LlaXFTQKFDgs5bTepcAo-AXHly9IDp_iZJE

Roy, A. (2005). Urban Informality: Toward an Epistemology of Planning. *Journal of the American Planning Association*, 71(2), 147–158.

Satterthwaite, D., Archer, D., Colenbrander, S., Dodman, D., Hardoy, J., Mitlin, D., & Patel, S. (2020). Building resilience to climate change in informal settlements. *One Earth*, 2(2), 143-156.

Schacher, T. (2014). Disaster-Risk Reduction through the Training of Masons and Public Information Campaigns: Experience of SDC's "Competence Centre for Reconstruction" in Haiti. In *Earthquake Hazard, Risk and Disasters* (pp. 55-69). Academic Press.

Smyth, C. G., & Royle, S. A. (2000). Urban landslide hazards: incidence and causative factors in Niterói, Rio de Janeiro State, Brazil. *Applied Geography*, 20(2), 95-118.

Soares, F., & Soares, Y. (2005). The socio-economic impact of favela-bairro: what do the data say?. *Inter-American Development Bank, Washington DC*.

UNDRR. (2019). Global Assessment Report on Disaster Risk Reduction, Geneva, Switzerland, United Nations Office for Disaster Risk Reduction (UNDRR).

UNDRR. (n.d.). Understanding Disaster Risk: Disaster Risk. *PreventionWeb*. United Nations Office for Disaster Risk Reduction (UNDRR). Retrieved 10.11.2021 from

<https://www.preventionweb.net/understanding-disaster-risk/component-risk/disaster-risk>

UN General Assembly. (2016). Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction. *United Nations General Assembly: New York, NY, USA, 41*.

UN-Habitat. (2003). The challenges of slums: Global report on human settlements 2003. London: Earthscan Publication Ltd.

UN Habitat. (2013). State of the world's cities 2012/2013: Prosperity of cities. Routledge.

Viva Rio. (n.d.a). De Olho no Lixo. *Viva Rio*. Retrieved 16.11.2021 from <http://vivario.org.br/de-olho-no-lixo/>

Viva Rio. (n.d.b). De Olho no Lixo – Prêmio Firjan Ambiental 2020 (2016-2021). *Viva Rio*. Retrieved 16.11.2021 from <http://vivario.org.br/de-olho-no-lixo/>

Vivenda. (n.d.a). Vivenda. *Vivenda*. Retrieved 17.11.2021 from <https://www.vivenda.io/>

Vivenda. (n.d.b). Instituto Vivenda. *Vivenda*. Retrieved 17.11.2021 from <https://www.institutovivenda.com.br/>

Vivenda. (n.d.c). Nova Vivenda. *Vivenda*. Retrieved 17.11.2021 from <https://www.novavivenda.com.br/>

Wekesa, B. W., Steyn, G. S., & Otieno, F. F. (2011). A review of physical and socio-economic characteristics and intervention approaches of informal settlements. *Habitat international*, 35(2), 238-245.

Williams, D. S., Manez Costa, M., Sutherland, C., Celliers, L., & Scheffran, J. (2019). Vulnerability of informal settlements in the context of rapid urbanization and climate change. *Environment and Urbanization*, 31(1), 157-176.

Williamson, T. (2021, October 26). *Rethinking the future of housing worldwide: Favelas as a sustainable model?* [Online Lecture]. INSIGHTS Public Lectures, Newcastle University.

https://www.youtube.com/watch?v=YI3eA7L9g9s&ab_channel=INSIGHTSPublicLectures

Figures

All images and figures in this paper were produced by the author (Reis, O.).

Annex A: Resident's Questionnaire Form (Translated from Portuguese)

Residents Survey on Building Process and Challenges in Rocinha

This short survey aims to get the residents' perspective regarding the challenges of the built environment in the community.

After a year and a half of living in Rocinha, I had decided to dedicate my master thesis in urban development to explore ways for improving the building processes, allowing a better quality of housing, and ensuring resilience against climate-related crises.

I hope to develop the thesis into a project that will offer architectural consultation in the community in the future.

I would appreciate it if you could dedicate a few minutes to answer the questions, and if you could share this survey with more residents.

The questionnaire is anonymous and is used for academic purposes only!

Thank you!

Oshi

* Required

General Information

1. Gender *

Mark only one oval.

Female

Male

Other

2. Age *

3. Street/ Area of living *

Challenges, Vulnerabilities, and Risks

4. What are the main challenges your home/Rocinha is facing? *

Check all that apply.

- Water supply
- Electricity supply
- Sewage and drainage
- Waste Management
- Houses Structure

- Ventilation and natural lighting
- Insulation and water penetration
- Accessibility

- Transportation
- Health services
- Education services

- Employment and Financial Opportunities Floods
- and landslides

- Drugs and organized crime Violence and
- Security

Other: _____

5. Would you like to add something or elaborate?

Assessment of challenges

In this section, you will be asked to assess the urgency of each problem. Your answer may refer to the situation in your own home or to your perception of the situation in the whole community. The scale works:

1= not urgent - there is no problem, everything is perfect.

5= very urgent - the solution to the problem is very urgent, the situation is very bad.

6. Water supply (lack of a water supply system? are there water shortages?)*

Mark only one oval.

	1	2	3	4	5	
not urgent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very urgent

7. Energy supply (do you lack electricity? are there electricity shortages?)*

Mark only one oval.

	1	2	3	4	5	
not urgent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very urgent

8. Sewage and drainage (do you have a sewerage system in the home? and in the street? is it overflowing?)*

Mark only one oval.

	1	2	3	4	5	
not urgent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very urgent

9. Waste Management *

Mark only one oval.

	1	2	3	4	5	
not urgent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very urgent

10. Houses Structure *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

11. Ventilation and natural lighting in the houses *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

12. Insulation and water penetration (does water come in from the roof or the walls?
is there moisture or mold?) *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

13. Accessibility (is your house/area/community reachable, are people with movement
disabilities able to get to where they need?) *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

14. Transportation (is public transportation services sufficient? inside the
community and commuting to other parts of the city?) *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

15. Health services provision *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

16. Education services provision *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

17. Employment and Financial Opportunities *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

18. Floods and landslides (how significant are the disasters arising from heavy rains in comparison to the daily challenges the community is facing?) *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

19. Drugs and organized crime *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

20. Violence and Security *

Mark only one oval.

1 2 3 4 5

not urgent very urgent

21. Would you like to add an issue or make a comment?

Housing situation

22. Has your house been affected by heavy rains? *

Mark only one oval.

- Yes
- No
- Don't know / Prefer not to say

23. Has your house been affected by shootings/war? *

Mark only one oval.

- Yes
- No
- Don't know / Prefer not to say

24. Has your house been affected by a neighboring construction? *

Mark only one oval.

- Yes
- No
- Don't know / Prefer not to say

25. If you answered yes to any of the above questions or if your home was affected by any other situation/disaster, can you explain or make a comment?

Housing General Information (optional)

26. Where do you live? (Housing type)

Mark only one oval.

- A building owned by me / my family
- An apartment owned by me / my family in a building A
- rented apartment
- A Kitenet (means a small dwelling unit) A
- house owned by me / my family
- A rented house
- Other: _____

27. How many floors does your building have?

28. How many floors does your home have?

29. If you are planning to expand your house/building, how many floors do you want to build in the future?

30. How many people are living in your house?

31. Would you like to make a comment?

Annex B: Guidelines for Documentation and Interview

Interviews:

1. General details (name, age, work)
2. How many people living at/using the home (also names, ages, occupation)
3. The story of the family (where did they come from, where are the relatives living)
4. Who/when started, what was the state of the land?
5. Land acquisition and title
6. Development timeline
7. Years of development and renovation (if there is no memory of the year to ask for how old were the kids when it happened, or what event happened at that time, and then trace the year)
8. What was constructed each time
9. Who lived where (family, rent, business, work at home)
10. What initiated the development (they got more money, changes in family structure, etc.)
11. Design and architecture - who did everything?
12. Construction consideration?
13. Building regulations- having neighbors affects the design?
14. If there were ever problems in the construction or design? (Water penetration, structural strength, infrastructure, etc.)
15. The legality of owning a house in the favela today- where is it registered?
16. The extension of the house – where do you... (Play as a kid, Social/family gathering)
17. The neighborhood- where do you... (Buy things, go to school, transportation, health, go out)

Documentation:

18. Old Pictures
19. Photography
20. Architectural drawing of what exists- plans, sections, sketches
21. Creating architectural drawings of the history of development, according to interviews
22. Sketches of development
23. Understanding infrastructure functions (water, water tanks, electricity, sewer).
24. Marking on drawings and documenting via photos challenges
25. Map of the location in the favela