



Predictive Slum Mapping: The Global Program of Resilient Housing and the World Bank's Experimentation with Geospatial Technologies

GEO 511 Master's Thesis

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Figure 1: In Villanueva, Guatemala, windows and garages are being detected by machine learning (Photo: World Bank)

How does the Global Program for Resilient Housing target disaster-prone informal settlements as experimental testbeds for geospatial technologies?

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Abstract

This thesis investigates the World Bank's Global Program for Resilient Housing (GPRH) and its experimentation with drone imagery, Street View, and machine learning to map disaster-prone informal settlements. The program operated across more than a dozen cities in Latin America, the Caribbean, and Indonesia, using these vulnerable settings as testbeds for geospatial technologies. This thesis applies methods from policy mobilities studies to trace the program's operation across different sites. This thesis draws on the extensive reports and technical guidelines published by the GPRH, as well as on 12 interviews with development specialists and geospatial technicians. It characterizes the program's approach to 'resilient housing' and examines the re-adaptation of its methodology to different urban environments and political contexts. It explains how the program's technical procedures translate urban materiality into housing data and legible risk maps, enabling new fields of intervention. Building on the concept of 'informational peripheries', the analysis demonstrates how such digital mapping technologies transform the governance of previously unmapped urban peripheries. The case illustrates how the World Bank intervenes at the municipal scale by developing assessment tools and building data capacities in the name of resilience.

Keywords: informational peripheries, slum mapping, urban resilience, housing data, anticipatory governance, urban governance, drones, algorithms, Street View, experimentation

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I dedicate this thesis to the memory of my grandfather, Rudolf, who worked with GIS and engaged with intricate survey error calculations long before I was born.

This thesis was inspired by the historians of science who taught me that mapping is always a material and political intervention; and the media scholars who taught me that maps are always operational, organizing our world, but also our skills and senses.

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Introduction: Camera, Drone, Laptop



Figure 2: Promotional image used in a blog post on the GPRH (GPRH 2022b).

Camera, Drone, Laptop. According to the Global Program for Resilient Housing (GPRH), these are the tools needed to “support governments to promote resilient housing, save and improve lives, protect assets, and shield economies from increasing disaster risks” (GPRH 2022b). As part of the Global Facility for Disaster Reduction and Recovery (GFDRR) managed by the World Bank, the program operates in multiple cities across Latin America, the Caribbean, and Indonesia. It has developed mapping methods that use drones, Street View imagery, and machine learning algorithms to assess the resilience of houses in disaster-prone informal settlements.¹ This methodology aims “to predict which houses are at the highest risk of getting damaged by natural hazards, to identify which can be made safe before it is too late, and to connect them with government subsidies and private capital”(GPRH 2022b). The GPRH exemplifies how the World Bank mobilizes geospatial technologies to digitalize urban peripheries in the name of resilience.

The GPRH promises to mitigate losses and damage from natural disasters by identifying the most vulnerable housing units before the next disaster. Unlike development programs focused on post-disaster damage assessments, the program conducts its mapping missions *ex ante* to guide retrofitting efforts that strengthen houses before the next disaster. This anticipatory mode of

¹ I use the term “informal settlements” to describe the urban spaces targeted by the GPRH, even if not all of them are informal in the legal sense. This best reflects how program members themselves described the spaces for which they developed their mapping methods. This is not neutral terminology but mirrors the operational logic of the program. I acknowledge that this framing does not address the complex politics around different definitions of informality, which can include “legal-regulatory”, “developmental”, and “morphological” framings (Shatkin, Braswell, and Martinus 2023, 943).

disaster risk management is best expressed by its slogan ‘Build Better Before’.² The GPRH thus addresses informal housing as a technoscientific object of prediction and anticipatory disaster management.

A core element of the GPRH has been the geospatial knowledge production of its ‘technology’ component, which resulted in replicable technical methods that render informal urban spaces ‘legible’ and amenable to a variety of governmental interventions and expand the data capacities of local governments. Since its inception in 2018, the GPRH has produced a wide variety of technical methods and outputs: A replicable methodology for ‘Rapid Housing Assessments’ using drones and Street View, training datasets consisting of tens of millions of urban images, and multiple machine learning models to classify houses according to different criteria. It also developed digital platforms for urban governance, such as ‘Housing Passports’ for individual houses and a ‘Housing Portal’ that visualizes houses as cadastral maps and classifies them by vulnerability, taxation, or property value.

The GPRH’s urban mapping constitutes a paradigmatic case of how emerging technologies of visualization and data analysis, such as drone mapping and machine learning algorithms, are rapidly transforming urban governance. This trend is not only evident in densely networked and data-saturated smart cities but also transforms “areas that were once remote and unseen into spaces that are increasingly visible, mapped, calculable and programmable” (Datta and Hoefsloot 2025c, 1). These transformations raise important critical questions regarding the actors, technologies, and epistemic operations involved in the translation of messy urban matters into digital data and legible visualizations.

Why has the World Bank become involved in the mapping of informal settlements down to the scale of individual housing units? And how does the GPRH’s institutional position at the Bank shape this geospatial knowledge production? Inspired by Donna Haraway’s evocative insight that “maps are models of worlds crafted through and for specific practices of intervening and particular ways of life” (1997, 135), this analysis of the GPRH’s technoscientific modes of seeing will provide some insight into these questions.

² ‘Build Better Before’ is the anticipatory version of ‘Build Back Better’, which has become the mainstream paradigm in post-disaster disaster management since around 2006 (Alvarez and Cardenas 2019; Borie and Fraser 2023; Cheek and Chmutina 2022; Hallegatte, Rentschler, and Walsh 2018).

Research Objectives

The first objective of my research is to characterise the GPRH as a development program and outline its approach to ‘resilient housing’. This involves describing its structure into three components and explaining its main aims and achievements. Identifying the distinct elements of its approach provides a backdrop for understanding how it deploys its technoscientific approach to urban observation.

My second objective is to trace the GPRH’s multi-sited mode of operation as a World Bank technical assistance program. My analysis focuses on the program’s ‘technology’ component, which primarily concerns the application of its sensing technologies and mapping methodology across different urban environments. This chapter particularly shows how the program’s approach and methods were adapted to different urban environments and contexts.

My third objective is to analyse GPRH’s data production, workflow, and algorithms. This involves examining how targeted informal settlements are visually captured and how machine learning models translate this housing data into legible risk maps. This entails attention to the hidden labour behind these technical procedures and a reflection on the many factors excluded from these housing assessments. This serves to identify critical elements in the process by which urban materiality is translated into legible data, and how this procedure shapes urban governance.

The fourth objective is to situate the GPRH in the World Bank’s broader engagement with data-driven development, particularly its production of geospatial knowledge and its advocacy of machine-learning tools for urban governance. While the program’s stated aim is the material improvement of the targeted settlements, some of its most important contributions are found in the circulation of its mapping methods and the algorithmic analysis of urban environments.

Through these four related research objectives, I demonstrate that the GPRH employs a technoscientific approach to urban resilience that renders informal housing into an object of prediction to guide anticipatory interventions. The program’s adaptation and experimentation with such technologies and algorithms across different urban contexts enables geospatial knowledge production that extends beyond the program. The case thereby illustrates how the GPRH engages in experimental geospatial knowledge production to map ‘informational peripheries’ in the name of resilience. The facilitation of such technoscientific modes of seeing the city through the World Bank demands closer attention to the epistemic and experimental dimensions of the implementation of ‘urban resilience’ across the Global South.

Research Questions

This master's thesis takes the global development program as its level of analysis, rather than a single urban setting that was mapped. My methodology draws on policy mobility studies to trace the program's operations across different sites and how this impacted its knowledge production. Empirically, the research builds on 12 expert interviews with development specialists and geospatial technicians, as well as an extensive document review of reports, blogs, and technical guidelines published by the GPRH. These methods provide insights into the GPRH's multi-sited operations, the experimental re-adaptation of its mapping methods, and the broader effects and policy changes achieved by the program.

With the overarching aim to analyse the GPRH as a case of how the World Bank engages in the experimental mapping of 'informational peripheries' in the name of resilience, I follow the overarching research questions:

How does the GPRH target disaster-prone informal settlements as experimental testbeds for geospatial technologies?

The question is again subdivided into four sub-questions, one for each main chapter:

What characterises the GPRH's approach to resilient housing and its rationale for mapping informal settlements?

How does the program operate across different urban settings, and how does this mobility shape the re-adaptation of its methods?

How does the GPRH's methodology translate the urban materiality of informal settlements into housing data and legible cadastral maps?

How are these mapping methods circulated beyond the program through the World Bank's institutional ecosystem?

Conceptual Perspective

This case study of the GPRH, particularly its 'technology' component, contributes to recent scholarship in geography in two ways. First, the analysis takes up the concept of 'informational peripheries' from very recent contributions at the intersection of urban and digital geography (Datta 2023; Datta and Hoefsloot 2025c). The GPRH provides a window into how informal settlements are targeted through mapping technologies to incorporate them into circuits of data and capital. This thesis foregrounds the open-ended and adaptive process by which "peripheral spaces and communities are becoming the experimental testbeds of new smart technologies for

visualisation, mapping and urban governance” (Datta and Hoefsloot 2025c, 3). The GPRH’s operations across different urban peripheries are not just employing technologies developed elsewhere; the program uses these environments as productive laboratories for the re-adaptation and experimentation of its methodology. Applying this conceptual perspective to the GPRH shows that it is not only the ‘digitalising state’, but also global development actors such as the World Bank, that engage in the “extraction, visualisation and representation of information about metropolitan regions” and advance the related “technocratisation of urban governance” (Datta 2023, 145).

The case of the GPRH also contributes to critical geographical scholarship on the implementation of ‘urban resilience’ across cities in the Global South, particularly by the World Bank (Bigger and Webber 2021). According to Sophie Webber and her coauthors, these efforts have evolved into a global project that can be conceptualised as a *‘global urban resilience complex’* (2021). They suggest that this complex comprises three main components: “a network of key organizations; a set of measurement, assessment, and institutionalization techniques and procedures; and experimental discourses and practices that seek to marketize urban resilience” (Webber, Leitner, and Sheppard 2021, 344). In their work on the Rockefeller Foundation, Helga Leitner and her coauthors have particularly noted that development programs particularly focus on the “development of technologies to assess, measure and implement urban resilience” (2018, 1278). This research expands these perspectives by offering a detailed account of the digital methods developed by the GPRH to assess resilience at the scale of individual housing units.

The fine-grained housing data produced by the GPRH across multiple cities has influenced housing policies, retrofitting interventions, and micro-finance programs. Beyond these local effects, these experiments also produced new forms of geospatial knowledge that circulate beyond these sites and are taken up by governments and other actors. This demonstrates how the program targets previously unmapped settlements in the name of resilience, simultaneously using these urban environments as testbeds for digital mapping technologies. The World Bank thereby increasingly assumes the role of a global facilitator of technoscientific modes of seeing and managing the city.

Literature Review

This chapter presents some relevant literature on related topics and situates the case study within existing geographical research. This serves to position the case at the intersection of previous studies on urban resilience, risk management, and cadastral surveys, and to present valuable work that has examined similar processes of knowledge-based interventions, risk mapping, or drone surveys.

The chapter first presents existing research on the institutional networks and situated experimentation related to the implementation of 'urban resilience' in the Global South. It then reviews research on the politics of knowledge and expertise in urban development and disaster management, particularly regarding spatial data and mapping practices. A further section presents previous research on urban risk management in the Global South, particularly Austin Zeiderman's book on the *Endangered City*, which serves as an important vantage point for this study. It then reviews studies on the fundamental role of cadastral surveys and property regimes, as well as studies on contemporary digitalization programs using geospatial technology. Finally, due to the GPRH's focus on visual assessments, studies on aesthetic modes of urban governance are reviewed. The chapter concludes with a short overview of existing research on the GPRH and by situating this case study in these literatures.

The Global Urban Resilience Complex

In her third urban geography progress report, Kate Derickson argues that the dawn of the Anthropocene has led to the combined promotion of *smart* and *resilient* cities, a paradigm she terms 'Anthropocene Urbanism' (2018). This has produced forms of 'anticipatory governance' which attempt to soothe scientific and political anxieties by calculating, predicting, and ultimately preparing for uncertain urban futures (Derickson 2018, 427). She warns, however, that the combined pursuit of smartness and resilience risks "collaps[ing] the political realm into the technocratic realm" (Derickson 2018, 431). Striking a similar tone, Stephanie Wakefield describes the emergence of experimental modes of governance that seek "to remodulate urban infrastructure amidst or in anticipation of [disruptive] events, in order to anticipate, buffer, and absorb their force" (2021, 333). While cities are seen as primary drivers of climate change, they are simultaneously deemed "especially promising sites for building resilience to it due to their ability to respond quickly via situated experiments" (Wakefield 2021, 331). The laboratories in which such experimentation takes place "is not the pristine or sterile space" of the modern laboratory, "but rather the urban environment itself" (Wakefield 2021, 336). These urban experiments are deemed necessary to develop monitoring technologies and governance

techniques capable of taming and responding to the uncertainties of climate change. The planetary conditions of the Anthropocene, therefore, give rise to technocratic modes of anticipatory governance, which increasingly rely on situated urban experiments in the name of resilience.

The concept of resilience is usually associated with building the adaptive capacities of cities and their inhabitants.³ It is especially dominant in the fields of climate change adaptation and disaster risk management. As highlighted by Maud Borie and her co-authors, “resilience has become a discursive field deployed to represent the city and particular visions of its future” (2019, 203). This has led some studies to engage with the discourses around ‘urban resilience’ and its many competing varieties (Meerow and Newell 2019).⁴ Other studies examined how powerful institutional actors, such as the Rockefeller Foundation (Coppola and Haupt 2023) or the World Bank (Bigger and Webber 2021), push specific versions of resilience into cities across the world, effectively ‘globalizing’ the concept (Leitner et al. 2018). Many critical studies have highlighted the inequalities and political contestation that can arise from the translation of ‘resilience’ into concrete urban measures (Grove, Cox, and Barnett 2020; Kaika 2017; Ranganathan and Bratman 2021). A shared critique of these studies is that the focus on resilience by development projects often occludes historical and structural questions about “the actors and processes that produce the need to build resilience in the first place” (Kaika 2017, 95).

These broader paradigms in urban governance also shape development interventions targeting cities in the Global South. Much recent research at the intersection of urban and development geography has examined the hegemony of the concept of ‘urban resilience’ in the development sector,⁵ particularly how the global circulation of knowledge and expertise surrounding its implementation shapes the adaptation strategies of cities worldwide. Webber, Leitner and Sheppard have argued that the promotion of ‘urban resilience’ has evolved into a global project that can be conceptualised as a ‘global urban resilience complex’ comprised of three main components: “a network of key organizations; a set of measurement, assessment, and institutionalization techniques and procedures; and experimental discourses and practices that

³ For example, one pertinent World Bank report defined resilience in an urban context as “the ability of a system, entity, community, or person to adapt to a variety of changing conditions and to withstand shocks while still maintaining its essential functions”(World Bank & GFDRR, 2015, p. 12).

⁴ Even within the World Bank, the concept of resilience is not consistently defined. For example, the ‘*Investing in Urban Resilience*’ Report lists 11 definitions in its annex (GFDRR 2015).

⁵ ‘Resilience’ centrally features on international development agendas such as the Sustainable Development Goals (SDG) (SDG 11: “Make cities and human settlements inclusive, safe, resilient and sustainable”) and the UN’s New Urban Agenda (United Nations 2016). The concept of resilience is also fundamental to the Sendai Framework for Disaster Risk Reduction (“Priority 3: Investing in disaster risk reduction for resilience”) (United Nations 2015).

seek to marketize urban resilience” (Webber, Leitner, and Sheppard 2021, 344). They suggest that this complex has shaped resilience norms and practice, not only through discourse, but also by “creating and promoting universal urban resilience assessment tools” which “render questions of urban resilience technical” (Leitner et al. 2018, 1282). The multicentric, networked nature of this ‘global urban resilience complex’ warrants close attention to how development organizations such as the World Bank position themselves within this constellation. The examination of the GPRH illustrates how such assessment tools emerge from the multi-sited operation of such development programs.

The global implementation of ‘urban resilience’ corresponds to a scalar shift, according to which development interventions increasingly target cities and municipalities, rather than the national policy level. Patrick Bigger and Sophie Webber have argued that this shift leads to what they term ‘Green Structural Adjustment’, new forms of development interventions that seek to “render cities investable through reforms in municipal governance, the production and analysis of environmental data, and various forms of administrative capacity building” (Bigger and Webber 2021, 37). The World Bank has been identified as a prime actor in this regard, due to its “geographical, financial, and technical reach”(Bigger and Webber 2021). Related research has highlighted that climate-related development initiatives push for profound institutional reforms but also “intervene at the level of knowledge transfer and technical support” by exerting influence on the data apparatus of targeted cities (Hilbrandt 2025, 8). This scalar shift warrants close attention to how global development organizations mobilize knowledge and shape the data capacities of municipal governments.

One particular World Bank program facilitating ‘urban resilience’ is the City Resilience Program (CRP), launched in 2017. The stated aim of this program is to empower “cities to pursue investments that build greater resilience to climate and disaster risks, and to access the financing necessary to ensure those investments come to fruition”(World Bank 2019c). The CRP provides cities with diagnostic tools such as a ‘City Scan’ that aim to fosters their geospatial capacities to “package, prioritize and design resilience enhancing investments” (GFDRR 2019, cited in Bigger and Webber 2021, 43f). Recognizing the broader efforts of the World Bank’s agenda of financialization, Patrick Bigger and Sophie Webber conclude that the CRP’s technical assistance “has shifted urban governance priorities to making resilience investable” by “working across city and national scales to transform policy environments and provide technical and geospatial solutions“(2021, 44f).

The GPRH analysed in this thesis advances its own version of ‘resilient housing’ by developing geospatial methods for assessing individual housing units. The GPRH and the CRP are both

managed by the World Bank and part of the GFDRR. They also operate in a similar way: both intervene at the urban scale and provide cities with geospatial assessment tools, producing urban data that their client governments supposedly lack. My case study thus heeds the call of Webber et al. that “much further research is needed to account for the ultimate effects of these programs, in a diversity of cities”(Webber, Leitner, and Sheppard 2021, 358). By examining the GPRH’s geospatial interventions in detail, this thesis expands the existing literature on the politics around the global implementation of urban resilience.

The Politics of Knowledge of Urban Resilience

This research focuses on the GPRH’s production of housing data, therefore exploring the World Bank’s unique role as a producer and global facilitator of geospatial knowledge in the name of resilience. Previous research has centred the epistemic dimension of development interventions focused on ‘urban resilience’ by drawing on science and technology studies (STS). This has produced insights into the politics of knowledge around the mobilization of mapping technologies and related forms of expertise for climate adaptation and for disaster risk management.

In their comparative study of development projects in Manila, Nairobi, and Cape Town, Marie Borie and her coauthors show that the knowledge practices employed across projects produce distinct narratives of urban resilience, leading to different outcomes (Borie, Pelling, et al. 2019). This master's thesis follows their suggestion to analyse how resilience “is constructed through particular knowledge-making practices, and by whom” and to consider “whose disciplines and expertise shape resilience strategies” (Borie, Pelling, et al. 2019, 204). The GPRH’s approach mobilizes the resilience narratives identified as “Natural Hazards”, “Planning Ahead”, as well as “Technocratic Resilience” (Borie, Pelling, et al. 2019, tbl. 1). These three resilience narratives commonly use science and technology for prediction, monitoring, and anticipation, and tend to be technocratic, closing down rather than opening up conversations.

A related study compares the use of mapping and spatial data across resilience and disaster management projects (Borie, Ziervogel, et al. 2019). The authors note that different scales of mapping can lead to “inevitable disjuncture between scientists, engineers, city planners and their institutions, and those eking out a living, often in the margins of cities“ (Borie, Ziervogel, et al. 2019, 8). To prevent social exclusions, they pose the need to “better weave together spatial data about physical structure at the city-level with lived experience at the local level” (Borie, Ziervogel, et al. 2019, 8). One of their core insights is that it was the “*process* of mapping” as well as the “*format* in which information was presented and mapped” that determined whether mapping efforts could open up conversations and foster engagement among different actors (Borie,

Ziervogel, et al. 2019, 4). Such studies on the politics of knowledge of ‘urban resilience’ emphasize the complex interplay among forms of knowledge, mapping practices, and different conceptions of resilience. These comparative findings are particularly important because they include alternative methods of mapping resilience, such as participatory mapping and creative practices, that are not explored in this thesis.

Critical disaster studies have also engaged with the politics of knowledge and expertise in disaster management (cf. Donovan 2017). In their comparison of ‘Build Back Better’ agendas in French and Dutch St. Martin, Borie and Fraser interrogate the politics of expertise “around particular reconstruction and recovery processes”, notably “how the objects of knowledge themselves, such as risk assessments or new building regulations, embody such power relations, values and discourses” (Borie and Fraser 2023, 2). Aiming to shift disaster management towards ‘Building Better Before’, the GPRH positions itself as an authority in producing geospatial knowledge to anticipate disasters and build preparedness.

The most important takeaway from such STS-induced studies is that “the processes of knowledge production matter as much as the knowledge itself” (Borie, Pelling, et al. 2019, 211). Building on these insights, this thesis traces how the GPRH positions itself within geospatial knowledge production on ‘housing resilience’ and examines the related epistemic objects and calculations.

Urban Risk Management

Austin Zeiderman’s book *The Endangered City* provides one of the most comprehensive studies of urban risk management in the Global South. The main objective of his book was to “understand why and how the endangered city had emerged in Colombia when it did, and along with it the imperative to govern the present in anticipation of future harm” (Zeiderman 2016, 27). This contextual ethnographic work on the politics of security and risk in Bogotá provides multiple vantage points for this analysis of the GPRH.

Housing constitutes one of the most central areas of urban risk management. Zeiderman thus examines how municipal housing agencies define, measure, and manage risk, and traces their “approach to governing the spaces and populations of the urban periphery”(2016, 27f). Particularly useful is his ethnography of “the ongoing process of designating certain areas of the city zones of high risk” in which he approaches “these zones not as static and self-evident spatial units but as techno-political objects” (Zeiderman 2016, 28). As the notion of risk is inherently future-oriented, the designation of such zones and preventive measures, such as resettlement programs, constitute prime examples of anticipatory forms of urban governance.

One of Zeiderman's observations is the fundamental role of geospatial information for the governing of urban risks. For example, he notes that risk information systems not only serve to locate risks but also oblige the state to "develop the techniques necessary to detect and measure them, and communicate this information" (Zeiderman 2016, 70). This includes inventories of vulnerable settlements based on detailed risk calculations, in some cases down to "the scale of the neighbourhood and the individual property" (Zeiderman 2016, 74). Zeiderman concludes that such geospatial systems allow the targeting of "high-risk activities, populations, and neighborhoods" and thereby enable a new "field of governmental intervention" (2016, 73).

While not as contextually grounded, my analysis of the GPRH's predictive mapping of urban peripheries directly extends such perspectives. They show how the World Bank's approach intervenes in urban risk management by providing governments with geospatial technology and producing fine-grained housing data.

Cadastral Surveys and Property Technologies

Capitalist property regimes fundamentally rely on the abstraction and measurement of space through technical operations. A fundamental vantage point for such a perspective is Nicholas Blomley's work on geographies of property violence, where he convincingly argues that techniques to measure and order space "play an important practical and ideological role in property's legitimation, foundation, and operation" (2003, 121). He names three distinct spatializations of property, the frontier, the survey, and the grid, all of which play an active role in producing an "abstract space" which appears "not as a set of social practices, but as a binary order" (Blomley 2003, 127). Similar attention to the "techniques for measuring land and controlling terrain" has also been fundamental to recent understandings of territory as a political technology (Elden 2010, 811f).

Such a perspective shifts attention to how space is captured, ordered, and produced through technical procedures and labour, and how this shapes governance and property relations. Particularly useful for the case analysed here is Blomley's argument that the cadastral survey renders "space as an object of calculation" (2003, 128). As he suggests, "the surveyor plays an important role in the inauguration of a particular view of space as detached and alienable and thus is deeply implicated in the ideological creation of property" (Blomley 2003, 135). Such a practice-oriented understanding shifts attention to the mapping practices used to establish formalized spatial orders. Ultimately, property regimes are not separable from the surveys and instruments used to mark and divide the spaces under consideration.

Many historical studies have focused on the fundamental role of cadastral surveys across different contexts. Brenna Bhandar, for example, has examined how land surveys and the ideology of property are deeply implicated in colonial systems of power, producing racialized conceptions of land as abstract, alienable, and available for possession (2018, 33–76). Other work emphasized the fundamental role of cartographic surveying for nation-building and military power (Gugerli and Speich 2002; Kaplan 2018, 34–67). Recent studies examined the open-ended yet thoroughly political process of contemporary cadastral enclosure across different empirical contexts. For example, the political geographer Rony Emmenegger analysed state-driven cadastral mapping of rural land in Ethiopian Somali. Focusing on “the actual process by which land use maps were created”, he explores “the embodied, social, and technical practices and performances” accompanying this cartographic enclosure (Emmenegger 2022, 228). This scholarly interest in the cadastral survey as a technique of abstraction and power makes it necessary to examine how different versions of such technical instruments are deployed, by whom, and the new forms of enclosure this enables.

In his examination of cadastral land surveys and the digitalization of traditional property systems in India, Thomas Cowan centred the labour and technical procedures involved in rendering land calculable and commodifiable, calling for more empirical engagement with “the complex and uncertain sociomaterial work of measuring and calculating land boundaries” (Cowan 2021, 446). He argues that such a perspective is fundamental to “appreciate the potential for new technologies to radically transform the uses of land, trajectories of urbanization and forms of government” (Cowan 2021, 456). Rather than overemphasising the novelty of digital technologies, this recognizes that digitalized property systems are always grafted onto historical property systems and social relations. This aligns with research on ‘informational peripheries’, which grounds contemporary property technologies “in their historical development from paper, to digital, to algorithmic systems” (Datta and Hoefsloot 2025b, 282).

The closest empirical point of reference for this thesis is Cowan's recent work on the Svamitva scheme in India, a large-scale land formalization program using drones and machine-learning algorithms. The Indian government employs such geospatial technologies to render collectively organised rural spaces into standardised, digitalised plots managed via GIS platforms. Through this, the scheme aims to “strengthen rural state capacity and streamline spatial planning strategies across government departments” (Cowan 2025a, 199). Drawing on the concept of ‘informational peripheries’, Cowan concludes that such land digitalisation programs essentially aim to render “previously unmapped and unmappable, uncounted and uncountable property

relations, mappable and countable to the registers of both the state and financial institutions” (2025a, 208).

These digitalisation programs subdivide land into bounded parcels, enabling their centralised management on digital platforms. A pertinent observation by Cowan is that such property digitalisation programmes are used as “tools of assetisation and platformisation”, which, due to them being linked with other state platforms and identification programs, also act as “conduits toward a configuration of new, and perhaps rather unpredictable, form of digital citizenship”(Cowan 2025a, 192). Cowan notes that in India, high-tech property technologies such as drone mapping and machine learning are primarily deployed in the periphery, acting as “the central instrument for the recalibration of core informational grammars through which both markets and governance take place” (Cowan 2025a, 196). In a related article, Cowan also directly investigates the deployment of drones and related geospatial technologies in such digitalisation schemes. Noting the technoscientific allure of drone vision, he writes that “it is this beguiling technological speed and neutrality that have made drones essential components of contemporary property digitisation programmes in India and beyond” (Cowan 2025b, 2).

These insights closely relate to the argument put forward by Asher Ghertner that digitalisation aims “to overcome opacity, to render ‘low resolution’ peripheries into quantifiable property, and to normalise propertied forms of citizenship“, and must therefore be understood as a “frontier technology” (Ghertner 2025, 296). This analysis of the GPRH’s drone surveys and Street View assessments takes such perspectives at heart. By focusing on the program’s multi-sited operations, this study examines the World Bank’s experimentation with digital survey methods and their application across different urban peripheries. Unpacking the digital enclosure of informal settlements offers insight into the sociomaterial complexities of the digitalisation of urban space and its implications for property regimes.

Rule by Aesthetics

The GPRH develops methods to visually capture urban space through drones and Street View imagery. The subsequent segmentation and classification using machine learning enable automated classification of houses based on aesthetic judgments. The case thus provides a window into what Asher Ghertner has called “the epistemological foundation of government”, a perspective that invites us to “rethink how it is that a state knows and directs its object” (2015, 1). The study thus speaks to research on the different modes of knowledge production through which the legibility of informal settlements is produced.

A particularly useful vantage point is Ghertner's work on 'aesthetic governmentality' in New Delhi. In his analysis of the management of slums, he traces "how the production of an aesthetic normativity replaced maps and statistics as the key mechanism of rule" (Ghertner 2015, 1). Examples of this aesthetic mode of governance include government officials conducting 'windshield surveys' from cars and judges invoking 'nuisance law' to issue demolition orders. Ghertner argues that such aesthetic judgments constitute "a mode of governing space based on codes of appearance rather than through the calculative instruments of map, census, and survey" (2015, 4). Contrasting the use of aesthetic criteria with earlier forms of slum management through surveys, Ghertner suggests that "these two moments relied on an epistemologically different set of calculative practices one statistical, the other aesthetic to render the slum intelligible and secure rule"(2010, 187). The GPRH's workflow fuses such aesthetic judgements with statistical algorithms by using machine learning to classify housing from urban imagery. The program's methods enable an automated identification of visual clues at larger scales, thereby integrating certain aesthetic norms about what 'resilience housing' looks like into urban governance.

Following Ghertner's invocation of Foucault, this requires attention to "the actual instruments that form and accumulate knowledge, the observational methods, the recording techniques" and "the diverse forms in which knowledge is consolidated and used to craft grids of intelligibility" (Ghertner 2015, footnote 47). In the context of contemporary data-driven urban governance and geospatial risk management systems, this requires examining the technical procedures, algorithms, and digital platforms that underpin such work.

Previous Work on the GPRH and Literature Gap

Previous work in the critical social sciences has made brief mentions of the GPRH. For example, it has been cited as an "articulation of resilience discourse and the diffusion of resilience norms by the World Bank" (Ferguson and Wollersheim 2020, 161) as well as an instance of municipal structural adjustment in Mexican cities (Hilbrandt 2025, 8). The most comprehensive analysis of the GPRH can be found in a short portrait in an article on climate finance, presented alongside other cases (Grafe et al. 2023). This examination of the GPRH suggests that the program showcases how "the World Bank seeks to extend its power over the management of knowledge across territory in ways that cut out and reach across the topographical space" (Grafe et al. 2023, 11).⁶

⁶ This work builds on two interviews with leaders of the GPRH conducted in 2021 and 2022, which were also included in the corpus of this thesis.

This master's thesis builds on these insights and extends them in two ways. Empirically, it builds on additional interviews with program members and reviews its many publications to trace the GPRH's multi-sited operations and the reapplication of its mapping methodology. Conceptually, the program is analysed as a case of how the World Bank digitalizes 'informational peripheries' and how the targeted urban environments serve as urban testbeds for geospatial technologies. This study thereby offers a closer examination of the program's global operations and the inner workings of its visual technologies and algorithms.

The literature review has situated the GPRH at the intersection of multiple strands of urban geography literature. This thesis expands this literature with a dedicated focus on the program's multi-sited operations and geospatial experiments. The digital technologies and assessment tools circulated in the name of 'urban resilience' are not only implemented in a 'top-down' manner but are themselves developed and adapted across different urban environments. This distinguishes the GPRH's housing assessments from previously studied state-driven property digitalization programs, which are usually more centralised and standardised. This demonstrates how the World Bank targets vulnerable urban settings as testbeds for new urban mapping technologies, and how the circulation of these methods leads to a mainstreaming of anticipatory and algorithmic modes of governance in the name of resilience.

Conceptual Framework

Informational Peripheries

To interrogate the case of the GPRH and its mapping of informal settlements, I build on very recent contributions around the concept of the ‘informational periphery’ at the intersection of digital and urban geography. This analytical perspective builds on the core premise that “the technologies for urban governance are not neutral” but rather “emerge out of techno-capitalist projects” (Datta and Hoefsloot 2025c, 3). The mapping technologies examined here emerge from the global development agenda of the World Bank and its attempts to incorporate urban peripheries into the circuits of data and capital.

In their edited volume on informational peripheries, Ayona Datta and Fenna Hoefsloot suggest that “territory needs to be examined through the informational capacities offered by new technologies of measuring, drawing and representing land and property ownership”(Datta and Hoefsloot 2025c, 1). They thereby expand Stuart Elden’s foundational suggestion that “Territory can be understood as a political technology” comprising “techniques for measuring land and controlling terrain”(Elden 2010, 811f). The examination of the drone and Street View cameras employed by the GPRH, therefore, offers insights for contemporary analyses of how urban territories are digitally captured, represented, and managed.

The increasing mediation of urban spaces by digital technologies also leads to new processes of marginalisation and social exclusion. This leads to the formation of peripheries which “are marked by both geographic and informational distance from the state” and inhabited by “subjects that are uncountable as well as territories that are unmappable” (Datta and Hoefsloot 2025c, 3). To study the emerging urban-digital configurations, Datta and Hoefsloot propose the concept of ‘informational peripheries’. These are defined “as a combination of digital, material, territorial, infrastructural and social marginalisations” which “are determined by a lack of access to informational flows” (Datta and Hoefsloot 2025c, 2). As marginalised territorial entities which are nevertheless “selectively targeted by digital surveillance”, informal settlements such as those targeted by the GPRH are named as prime examples of such ‘informational peripheries’ (Datta 2023, 115).

Drawing on this framework, my research examines how the GPRH digitalizes urban peripheries through mapping. To operationalize the concept for my case, I employ the spatial-analytical lens focused on *the production of the informational periphery*. As Ashner Ghertner summarized well in

the epilogue, this perspective “focuses on the labour and bureaucratic practices of bringing urban peripheries into digital legibility” (Ghertner 2025, 292).

This perspective extends a tradition building on the work of James C. Scott, who famously argued that the ‘legibility’ produced through epistemic tools of statecraft, from cadastral surveys to censuses, is fundamental to ‘seeing like a state’ (Scott 1998). According to this line of thought, it is the abstraction of diverse social and environmental matters into simplified representations that renders territories and populations ‘governable’. Scholarship on ‘informational peripheries’ pushes this further, highlighting that “with the shift to new methods of recording, registering, storing and searching, digital technologies are transforming how states are seeing their subjects and territories” (Datta & Hoefsloot, 2025c, p. 10). In the case examined here, these modes of seeing are not implemented by the ‘digitalising state’ alone (Datta, 2023) but primarily driven by a global development institution: the World Bank.

The GPRH explicitly frames its work as closing a perceived ‘information gap’ between these urban peripheries, local governments, and the private sector. This aligns well with the idea that ‘informational peripheries’ are “paradoxical spaces that are at once marked by invisibility, exclusion and marginalisation while at the same time being targeted for incorporation into the territory of the metropolitan city” (Datta and Hoefsloot 2025c, 4). This incorporation is justified by posing the need for anticipatory disaster risk management. Applying the concept of ‘Informational peripheries’ for the analysis of the GPRH, therefore, fosters a critical understanding of how peripheral urban spaces in the Global South are being digitally enclosed in the name of resilience.

Geographies of Algorithmic Violence

As a second conceptual framework, I draw on Sara Safransky's recent framework on the ‘geographies of algorithmic violence’. Describing the unequal consequences of data-driven algorithms for market value analysis, implemented in Detroit, she puts forward the main argument “that the expanded use of data-driven analytics and algorithmic planning demands theoretical and empirical attention to geographies of algorithmic violence” (Safransky 2020, 200). She suggests that the apolitical and objective allure of data-driven tools in urban governance provides an imperative to re-politicize the way algorithms work by drawing attention to “how and to what effect they are transforming spatial relations in cities, and, in particular, their stakes for poor and marginalized residents” (Safransky 2020, 202).

Rather than merely demanding transparency about the way algorithms work, for example, how specific indices are calculated, Safransky advocates for a contextual analysis which examines “how particular political, social, economic, and geographical conjunctures lay the *conditions of*

possibility for harmful algorithmic assemblages to emerge in the first place” (Safransky 2020, 206, my emphasis). Drawing on such a perspective, this analysis aims to situate the algorithms produced and circulated by the GPRH within the World Bank’s broader engagement with disaster risk management and algorithmic governance.

Heeding Safransky’s call to examine the inner workings and unequal effects of algorithms, the third chapter of my thesis will engage in depth with the visual methods and classification algorithms developed by the GPRH. While promising an objective assessment of the vulnerability of housing units, these methods are always based on certain assumptions, have practical limitations, and can be used in ways that may have unintended effects. As a tool of algorithmic governance, the GPRH’s mapping procedure and data analysis shape who is eligible for housing subsidies or retrofitting, thereby removing some decisions from political deliberation. Safransky suggests that “understanding the traction and power of algorithms thus involves interrogating the epistemologies on which they are based and conversely, those that they exclude” (Safransky 2020, 206). In my case, this means relating the GPRH’s mapping technologies and machine-learning models to the broader paradigms of data-driven development and recent forms of ‘green structural adjustment’ pushed by the World Bank (cf. Bigger and Webber 2021).

Combining these two conceptual perspectives allows me to engage with the way digital technologies and algorithms are employed by the World Bank to target informal settlements across the Global South. The literature on ‘informational peripheries’ provides a rich conceptual framework for studying the targeting of urban peripheries through digitalisation schemes and recognises the continuities and frictions between digital property systems and forms of bureaucratic governance. The perspective on Geographies of Algorithmic Violence, suggested by Safransky, poses critical questions about the inner workings and unequal outcomes of algorithmic governance, pointing to the wider conditions of possibility that enable algorithms to gain legitimacy as tools of urban governance.

Research Design and Methodology

The GPRH conducts geospatial mapping of informal settlements to predict housing units at risk and shares these methods for replication. The targeted settlements are thus seen as urban spaces for material improvement but simultaneously serve as testbeds for the development of innovative geospatial methods. The experimental adaptation of mapping methods, training data, and algorithms across different sites is therefore crucial for understanding the GPRH’s approach. My research aims to analyse the geospatial knowledge production of the program and trace how

housing data and outputs through its mapping missions circulate between its sites and beyond the program itself.

Primarily focusing on the 'technology' component of the program, my research examines the mapping methods it developed and the housing data it produced. My methodology was chosen to account for the GPRH's multi-sited and adaptable mode of operation, and how the geospatial knowledge produced by the program recursively impacts urban governance and future interventions.

Methodology: Follow the Development Program

My research is centred on the GPRH's 'technology' component and its multi-sited geospatial knowledge production. To trace the operations of the GPRH and different applications and replications of its approach across different sites, I build on methodological approaches from geographical studies of policy mobilities (Peck and Theodore 2012; Wood 2016). The primary aim of data collection was to understand the GPRH's multi-sited operations and the mapping it conducted across different cities.

My methodology can broadly be described as 'Follow the Development Program'. The GPRH operates through technical assistance partnerships and conducts housing assessments across different cities, allowing for experimentation with its mapping methods and algorithms. As these engagements are accompanied by broader policy advocacy, the mapping missions often go hand in hand with changes in housing policy. The program also shares its methods and learnings through reports and technical notes. The material processes and networks through which the program operates and circulates its methods mirror those of mobile policies. The advantages of such a methodological approach are its sensitivity to movement, as well as to variable experiences in "sites of adoption/emulation", which act "as a spur to further experimentation and adaptation" (Peck and Theodore 2012, 24). This methodology is especially suitable for tracing the operations of development programs attached to the World Bank. Having rebranded itself as a 'Knowledge Bank' (World Bank 2024), many of the World Bank's global programs and partnerships constitute such multi-sited networks of knowledge production and circulation.

Data Collection

For data collection, I relied on Astrid Wood's methodology for researching policy mobilities, which she outlines as a set of three practical procedures and related to a set of challenges (Wood 2016). These methods provide insight into the translation process and the rationales behind policy adoption in certain localities. My data collection aimed to trace the GPRH's operations since its

conception and the application of its methodology across its various mapping sites. This was done through multiple interviews with key program members and specialists from related organisations and an in-depth analysis of the GPRH's published reports and technical documents. Focusing on the GPRH's geospatial knowledge production, such perspectives allow me to "study through" the members and sites of this global development program (cf. McCann and Ward 2012).

Follow the People: Expert Interviews

The first method proposed by Astrid Wood is to 'Follow the People', which typically takes the form of interviews. Speaking to policy actors provides valuable insights into the work and practical challenges that remained inaccessible through documents alone, allowing me "to trace the learning through the perspective of those directly engaged with the application of mobile ideas" (Wood 2016, 397). The interviews thus complement the formal and technical publications on the GPRH with practical perspectives on its approach and operations. To find suitable interview partners reviewed key reports on the GPRH and identified important contributors.⁷

The leading members of the GPRH acted as the principal authors of the most important reports and were easily to identify. The roles of other team members within the program were diverse and often highly specialised. Many interviewees had worked with the program on a temporary basis, limiting their involvement to specific sites, whereas many technical specialists only worked on specific steps of the GPRH's workflow. Many interviewees mentioned their limited perspective on the program's full operations, especially those who were responsible for highly specialised tasks.⁸ This also revealed the networked organization of this global development program and the division of labour between its different components and forms of expertise.

When reaching out to potential interviewees via email, I attached a 'Research Brief' [Annex 1: Research Brief] that stated my institutional affiliation and summarized the topic and aims of my research. The interviews were all held virtually (via Zoom, Teams, or telephone). While not as intimate as in-person interviews, this enabled me to talk to program associates stationed around the world. At the beginning of each interview, I allowed for questions or clarifications and obtained consent to record the interview, confirming that the data would be anonymized before publication.

⁷ The 'acknowledgments' of World Bank reports usually list the contributors and define their roles in the respective project. Starting from this basic information, I conducted additional research on social media platforms, WB Blogs, and Google Scholar to gather more information about their specialization and work experience.

⁸ Some interviewees were no longer involved in the project at the time of the interview, which limited insights to retrospective accounts; however, it also allowed them to reflect and speak freely about their work.

To account for the diversity and division of labour within the GPRH, I prepared personalised interview guides tailored to the specialised roles of my interviewees. I followed a three-pronged typology of actors to structure my interview guides and design questions (Annex 2 & 3). The combined perspectives of development specialists, technical experts, and associated organizations painted a comprehensive picture of the program's approach and operation.

The first category encompassed World Bank development specialists who held leading positions in the program. They were responsible for the conceptual and operational lead of the GPRH. These interviews provided insight into the organization of the World Bank's technical assistance to local governments, as well as the funding and planning of the program's mapping missions. As long-standing Bank employees with experience across various development projects, this also yielded insights into the GPRH's position within the World Bank's broader ecosystem.

A second category consisted of specialists and geospatial experts responsible for the technical components of the GPRH, such as data collection, processing, and analysis. This includes drone pilots involved in mapping missions, GIS specialists, and data analysts. Some of the interviewees worked at private geospatial companies such as 'Development Seed' or 'GeoCompas', which handled outsourced work packages, including manual labelling or training machine learning models.

A third set of interviewees consisted of individuals who were more loosely associated with the GPRH but familiar with its approach and engaged with its work and data. These included a program director of 'Build Change', a philanthropy advocating for housing retrofitting, which was heavily involved in the initial conceptualization of the GPRH's approach. Additionally, I conducted interviews with a leading geospatial expert and a junior data at the GFDRR specialist who have reused some of GPRH's rooftop imagery for a similar disaster management project in the Caribbean.

I conducted these interviews as semi-structured expert interviews. The interviewees were selected based on "their knowledge in a specific field of activity" and them being "employees of an organisation in a specific function" (Mattisek, Reuber, and Pfaffenbac 2013, 175, my translation). While acknowledging their expertise in their respective fields, there are two important caveats regarding the status of this expertise in my analysis. First, such interviews have limitations, as they are "somewhat staged and often rather scripted encounters" (Peck and Theodore 2012, 26). This was especially noticeable when seasoned World Bank officials re-narrated the same arguments as the official documents. Second, being interested in the geospatial knowledge production of the World Bank, I recognise the situatedness of *all* knowledge

production, including my own (Haraway 1988). This warranted careful reflection on the partiality of these perspectives and the structural conditions that lend them their authority and global traction (Goldman 2005).

The Interviews generally went very well and led to interesting conversations. Most of the interviewees were passionate and knowledgeable about their work and discussed the program's organisation and technical procedures. This provided insights into the program that were otherwise not accessible to me as an outsider. The interviews also allowed me to raise critical questions and build an understanding of the rationales behind the program's approach.

Although not all individuals contacted for an interview were responsive or available, I was able to conduct ten interviews, including with two long-term leaders of the program. I also had access to the transcriptions of two additional interviews with GPRH members conducted before the start of my thesis as part of a research project on climate finance. My final corpus comprises 12 interviews.

Description	Organisation	Description	Date
Senior Urban Development Specialist	World Bank	<ul style="list-style-type: none"> – Founder and operational lead of the GPRH – Involved in the coordination of mapping missions with local governments, policy advocacy, and private sector outreach 	20.1.2022 04.06.2025
Senior Geospatial Specialist	World Bank	<ul style="list-style-type: none"> – Long-term member and technical lead of the GPRH – Involved in managing partnerships with local governments 	23.04.2025
Senior Urban Development Specialist	World Bank	<ul style="list-style-type: none"> – Leading WB urban specialist of the program with broad experience in the development sector of the region 	12.10.2021
Senior Urban Development Specialist	World Bank	<ul style="list-style-type: none"> – Associate of the GPRH who worked on related development projects in Latin America 	27.01.2025
Consultant, Data Scientist	World Bank	<ul style="list-style-type: none"> – Collected, managed, and processed Street View data – Contributed to Guidance Notes 	10.03.2025
Drone Specialist	World Bank	<ul style="list-style-type: none"> – Drone pilot and aerial survey specialist who coordinated drone mapping in multiple sites 	05.04.2025
Data Scientist	Development Seed	<ul style="list-style-type: none"> – Program Coordinator of the external geospatial company Development Seed – Operational lead in multiple partnerships with the WB 	25.02.2025
Data Scientist	GeoCompas	<ul style="list-style-type: none"> – Geospatial analyst who worked with GPRH data for developing data processing tools and labelling 	13.03.2025
Program Director	Build Change	<ul style="list-style-type: none"> – Program director at Build Change 	26.03.2025

		– Former country director in countries where GPRH was active	
Senior Data Scientist	GFDRR	– Data Scientist, with vast experience in urban mapping with ML – Part of multiple geospatial projects within the World Bank	27.03.2025
Junior Data Scientist	GFDRR	– Re-used the GPRH’s drone imagery and methods for a GFDRR project in the Caribbean – Author of publications on the use of ML for development	27.03.2025
Development Specialist	World Bank	– Associate of the GPRH, co-authored early work related to its approach, and worked on some of its reports	13.02.2025

Follow the Materials: Reports and Technical Papers

As a second methods, Wood suggests to follow “the materials of circulation” (Wood 2016, 399). This involves examining the material artefacts through which policies are transmitted between different cities. She suggests that this is not about the materials per se but requires the researcher to remain “focused on the human decisions inspired by (and perhaps limited by) the materiality” (Wood 2016, 399).

The GPRH published multiple reports on its operations, which constitute my most important source. These documents outline the program’s approach and methodology, as well as the conclusions and policy recommendations derived from it. The reports are typically co-authored by one or two leading WB urban specialists and a varying team of development specialists, local consultants, and technicians, depending on the report's geographical and thematic focus.

Country reports include detailed documentation of the GPRH's engagement across different cities and its policy recommendations to national governments. These include the first comprehensive publication of the program, the “*Improving Housing Resilience: Synthesis Report*” (2019) on pilot projects conducted in two Mexican cities, the report “*La Vivienda en el Peru*” (2021) or “*Striking a Balance: Towards a Comprehensive Housing Policy for a Post-COVID Colombia*” (2021). These sources allow a reconstruction of the program’s work, detailing the rationales behind its engagement in specific countries and how its mapping missions were embedded into different national policy contexts.

Technical Guidance Notes focus more on the geospatial methods used by the program and are primarily aimed at technical experts. These detail the technical procedures of mapping and data analysis, as well as practical challenges in the ‘field’. These include the Guidance note on

“Capturing Housing Data in Small Island Development States” (2022) and the technical report on “Detecting Urban Clues for Road Safety” (2021). The latter documents a unique collaboration between the GPRH and the Global Road Safety Partnership where the program’s assessment methodology was adapted from housing resilience to road safety.

Multi-country reports, such as “Managing Environmental and Social Risks in Resilient Housing Projects” (2022) or “El costo y la accesibilidad de las soluciones de vivienda en América Latina y el Caribe” (2022), provide comparative insights from case studies across different countries and cities. They reflect the program’s regional focus on Latin America and the Caribbean and its efforts to use its position to synthesize learnings across different cities.

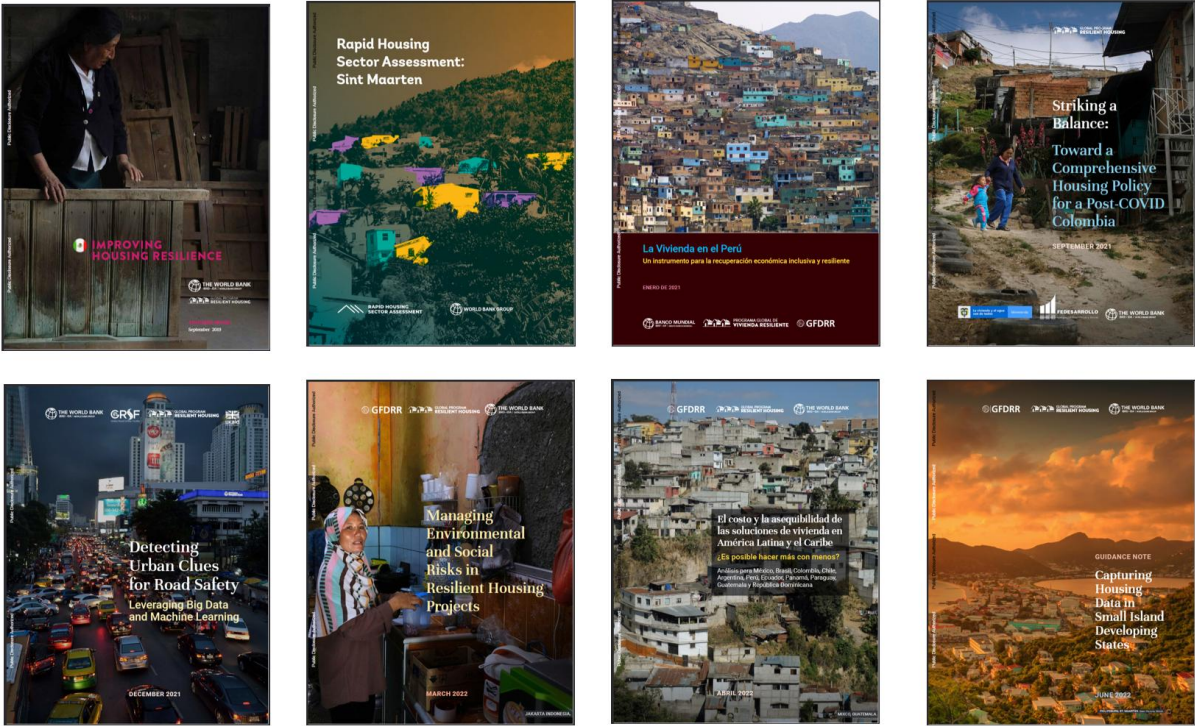


Figure 3: The eight GPRH reports at the centre of my document analysis. While differing in their respective aim and topic, they showcase the experimental and technoscientific approach of the program and its multi-sited operations.

Another important source directly related to the GPRH’s geospatial knowledge production was technical papers on its machine learning algorithms and urban mapping methods, published in journals such as *Automation in Construction*, *Buildings*, *Environment and Planning B: Urban Analytics and City Science*, and *Computer Vision and Pattern Recognition*. I also reviewed broader housing policy reports and World Bank strategy papers authored by program members or referenced in interviews. These publications provided insight into the program's high ambitions for knowledge production, as well as into how its methods and learnings are circulated beyond the World Bank's institutional boundaries.

To examine how the GPRH frames its approach and presents its methods to a broader audience, I reviewed its public outreach media. The World Bank Blogs were a particularly useful source in this regard. In these public blog posts, development specialists share key takeaways from their work and projects with a broader audience. Multiple specialists associated with the GPRH wrote blog posts on various aspects of the program. Some of these date back to before the program’s formal establishment and show overarching continuities in the approach chosen. These blogs also contribute to internal discussions at the World Bank, aiming to create visibility for the program and facilitate new partnerships.

To situate the GPRH within broader paradigms in the development sector, I consulted reports on urban resilience and disaster management by the World Bank and GFDRR. These included the World Bank’s flagship reports, particularly the World Development Reports on “*Data for Better Lives*” (2021) and “*Risk and Opportunity – Managing Risk for Development*” (2014). Due to the program’s focus on geospatial technology, I also consulted technical guidance notes related to the use of machine learning and drones in development, some of which were co-authored by individuals involved in the GPRH.⁹ Another helpful resource was the annual reports of the GFDRR, which provided brief descriptions of selected operations of the program.

<i>Reports and Documents</i>
<ul style="list-style-type: none"> • GPRH Reports • WB Flagship Reports and GFDRR Annual Reports • WB Blogs, YouTube Videos, and Presentations • Technical Articles

All documents and data used in my analysis of the GPRH were publicly available online. Almost all of the Street View imagery produced by the program could be freely accessed on Mapillary (~2 million images or ~4’600 km of streets) and some of its drone imagery on OpenAerialMap. The program also hosts a custom-made ‘housing portal’ to share housing data with relevant stakeholders. I was informed that access is limited to World Bank employees, as it is still a prototype. My access to projects and engagements was generally filtered by the information the World Bank chose to publish, thereby being mediated by its own documentation frameworks.

Follow the Meetings: Presentations and Promotional Media

As a third method, Wood suggests to ‘Follow the Meetings’. She argues that events such as workshops, seminars, and other gatherings “animate the various guides and reports, endowing certain models with the energy to circulate”(Wood 2016, 400). While some presentations on the

⁹ (GFDRR 2021b; The World Bank 2022; The World Bank, GFDRR 2018; World Bank 2019d)

GPRH were available online, the physical attendance of such meetings was not possible. However, I considered the slides from presentations on the program given at various international conferences on development and disaster risk, as well as multiple YouTube videos and two podcasts about the GPRH. While not as in-depth as the reports, these media showed the narratives and visual elements used to introduce and frame the program's approach. The abundance of such promotional materials on the GPRH thus still provided some insight into the "assemblages of knowledge circulation" that make up the World Bank's broader ecosystem of meetings and conferences (Wood 2016, 400).

Drawing on these three methodological procedures allowed me to start my research in a straightforward and exploratory manner with a strict focus on the GPRH and the associated people: "Practically speaking, we begin by gathering any and all materials used for the generation and translation of knowledge" (Wood 2016, 399). This approach to data collection proved fruitful in capturing the full scope and flexibility of the GPRH's multi-sited operation. This produced valuable insights into the continuous re-adaptation of its methods and its advanced geospatial knowledge production.

Data Analysis

The analysis of my source materials was guided by my research question and conceptual interests. While attempting to create a comprehensive picture of the GPRH's global operations and outputs, the primary focus was on the technical methodology and geospatial knowledge production. I therefore did not engage with all the content discussed in the reports to the same depth. For example, extensive discussions of national-level housing policies or technical assistance, sometimes contributed by government partners or Build Change, were only superficially analysed. The reports on the mapping procedure and data processing, as well as conceptual and methodological sections related to the program's 'technology' component, were more thoroughly examined.

I used the MaxQDA software to organize the GPRH reports and interview transcripts and code them according to recurring themes. After an initial scoping of my most important sources, a preliminary coding scheme was developed based on the research questions. During the detailed document analysis and in parallel with conducting the guided interviews, the coding structure was inductively modified into a robust set of categories relevant to my conceptual analysis. The coding scheme was further adjusted during the writing process, during which some elements proved more relevant than others.

<p>The GPRH</p> <ul style="list-style-type: none"> • Stated Aims • Inspirations, Related Programs • Problems / Gaps • Concepts / Approach <ul style="list-style-type: none"> ○ Use of Technology ○ Retrofitting / Qualitative Deficit ○ Build Better Before / Anticipation ○ Property Regularization ○ Housing Policy ○ Partnerships (Build Change, Development Seed) 	<p>Multisited Operation</p> <ul style="list-style-type: none"> • World Bank / Technical Assistance / Funding • Targeting / Areas of Interest • Mapping Sites / Local Contexts <ul style="list-style-type: none"> ○ Subcodes for each Site • Experimentation / Adaptation • Replications (by other actors)
<p>Mapping Workflow</p> <ul style="list-style-type: none"> • Workflow / Division of Labour • Data Capture / Fieldwork • Data Processing / Labeling • Machine Learning / Classification • Data Sharing / Data Use • Practical Challenges / Limitations • Uncertainty / Data Quality • Ethics / Privacy 	<p>Geospatial Knowledge Bank</p> <ul style="list-style-type: none"> • Geospatial Expertise at the Bank • Mainstreaming • Technological Trends • Future Prospects

The public outreach media on the GPRH (Blogs, Videos, Presentations) often conveyed the main conclusions of the reports to a wider audience. The analysis of these materials primarily served to reconstruct the chronology and evolution of the program and to examine the framing of its approach. To highlight and extract relevant citations, I downloaded and managed these materials in the literature software Zotero.

Research Ethics

The interviews were recorded only after receiving explicit consent from the interviewees and informing them of the subsequent analysis procedure. All interview transcripts were anonymised for the write-up, with names replaced by a broad description of their function. Anonymising the program itself would not have made sense given its specialised nature. As the program has a small team size, some caveats regarding complete anonymity had to be made. The cited reports and blogs typically list all authors by name, making it relatively easy to identify key members of the program. But as many of the interviewed World Bank specialists and consultants have published on the topic under their own names, the privacy issue regarding my interviewees is largely unproblematic. The selection of quotes and data presented in my thesis was guided by my respect for the time and openness my interviewees offered, and I was careful not to misrepresent their work or intentions.

Due to the limitations of the chosen focus and methodology, the exclusion of the perspectives of the populations from the World Bank's knowledge production could only be acknowledged but not rectified. Apart from this, no particular ethical issues arise from how the research was conducted (cf. Peake, Razavi, and Smyth 2024).

Positionality

My positionality as a white male researcher with a strong interest in mapping and surveying has overdetermined my access to the case at hand and ultimately shaped the perspective taken. My apprenticeship as an IT systems engineer and later studies in GIS and remote sensing enabled me to converse with World Bank development consultants and geospatial specialists about mapping and related data analytics. My familiarity with such technical work enabled me to tease out interesting aspects of the program that would otherwise be less accessible. My training in critical human geography and history of science sharpened my attention to the powerful assumptions, sociotechnical infrastructures, and social exclusions inherent to the mapping procedures of this World Bank program. While the program could have been analysed from entirely different perspectives, my material and social positionality fundamentally shaped which aspects were accessible and interesting to me.

My daily life in Switzerland, surrounded by thoroughly engineered urban landscapes and data-saturated property systems, differs radically from that of the people who are targeted by the GPRH's mapping missions. This led me to critically reflect on the limits of my own perspective as a critical academic who, similar to the program, observes such forms of uneven urban development '*from continents away*', largely shrouded from the conditions and perspectives of the people affected by them. Being transparent about the partiality and situatedness of my own perspective, I do not claim to know much about the urban spaces mapped by the program, nor about how the World Bank's data production and its translation into housing policies or retrofitting are received by the targeted populations.

Limitations

The GPRH's geospatial knowledge production is tightly coupled with the urban contexts in which it operates. My data collection and analysis primarily concern the program's geospatial technologies and examine the multi-sited operation of the GPRH across different cities. This multi-sited mode of operation is formative for the program's geospatial knowledge production and might have been overlooked if the focus had been on a single site. However, the chosen methodological approach provides minimal insights into GPRH's work in distinct localities and excludes the perspectives and livelihoods of the inhabitants of the targeted settlements. These

limitations reflect “the inescapable trade-off between the situational depth [...] achievable in long-duration, single-site ethnographies” and multi-sited “network-centric perspectives” (Peck and Theodore 2012, 25). A deeper engagement with the local contexts and material outcomes of the program’s mapping missions would require in-depth ethnographic engagement beyond the scope of the master's thesis. Choosing the global development program as my unit of analysis allowed me to explore the World Bank’s increasing engagement in geospatial methods and urban data production, which are viable and important objects of critical analysis in their own way.

The Global Program for Resilient Housing

The GPRH’s unique approach to ‘resilient housing’ fuses a range of different objectives and development paradigms. The program’s synthesis report on housing resilience defines its version of ‘resilience’ as “the capacity of housing units to protect lives and/or assets when unfavorable events occur” (GPRH 2019a, 47). This approach emerged from a hybrid constellation of actors, including the NGO Build Change, or geospatial companies such as Development Seed. This chapter characterizes the GPRH’s approach to resilient housing and outlines its rationale of mapping informal settlements.

It will first outline the program's structure into three distinct components: technology, technical assistance, and policy advocacy, the first of which is the primary focus of this thesis. It will then outline some of the most important elements of the program: how it addresses the qualitative housing deficit, the assumed ‘information gap’ between local governments and informal settlements, and finally its technoscientific mode of urban observation and geospatial experimentation, as well as the temporal shift towards ‘Building Better Before’. This introduction of the GPRH and its approach serves as a backdrop for the later focus on its different mapping missions and the detailed examination of its technical methodology.

Introduction to the GPRH

The GPRH was formally announced on October 3, 2018, at a public event in Washington, D.C., co-hosted by the World Bank and the NGO Build Change. According to a World Bank official, this new program “will leverage machine learning and geospatial technology to inform policy actions in the developing world” and hopes to “develop a pipeline of new projects that increase the resilience of the existing housing stock” (C+S Engineer Media 2018). The program’s engagement primarily concerns the safety and structural integrity of millions of homes in the developing world, “many of them built with haphazard materials and informal methods that leave them particularly vulnerable” (Build Change 2018). Luis Triveno, a World Bank urban specialist and founding

member, introduced the GPRH as the first Bank program to focus “on improving the safety of existing housing rather than on broader infrastructure projects or new construction initiatives” (Build Change 2018). The GPRH frames substandard housing not as a socio-political condition but as a technical problem to be addressed through geospatial technology. This orientation prefigures the program’s later operations and shapes its ongoing geospatial experimentation.

The program’s foundation emerged from a partnership between two organisations: the World Bank, a global development institution, and Build Change, a non-governmental organisation specializing in structural engineering. The latter has advocated for housing retrofitting to mitigate the vulnerabilities of people living in substandard housing since 2004. Elizabeth Hausler, the CEO of Build Change, emphasized the advantages of housing retrofitting at the opening event: “This is easy, and it’s cost effective. We know why these buildings collapse in earthquakes, we know how to retrofit them” (Build Change 2018). Through the partnership with the World Bank, this approach would now be adopted and supported by a leading global development institution. As highlighted by Build Change’s program director at the event: “It is very encouraging to see them taking this work to a global practice level to be funded and implemented hopefully in many countries around the world” (Build Change 2018).¹⁰

Since its foundation in 2018, the GPRH has conducted numerous mapping missions and policy-related engagements across cities in the Global South. This section introduces the program’s organizational structure and characterizes its approach to resilient housing.

The name of the program and approach, ‘Resilient Housing’, was coined by Build Change and The World Bank. A leading member of the program suggested that the adoption of certain concepts that dominate global development discourse was useful to channel funding towards the urban poor. He suggested that ‘Resilience’ was “another buzzword that is coming from the West and climate change...” and that they adopted this framing to shift improvement programs and channel funding towards protecting the urban poor. He framed this as a common rationale of the “technical Intelligenzija” according to which “if we really want to protect the poor, we need to incorporate resilience, we need to incorporate green design” (Interview, 20.01.22, S. 4).¹¹ This

¹⁰ The collaboration between the World Bank and Build Change can be seen as an instance of the World Bank’s continuous experimentation with housing policy in Latin America, in which it “has shown eager interest in learning from [...] non-profit actors and, potentially, appropriating their tools and approaches” (Grubbauer and Escobar 2021, 554).

¹¹ This resembles the strategy of Colombian government officials described by Zeidermann, who claimed that by adopting hegemonial risk management principles, municipal agencies “had found a way to give housing subsidies to disadvantaged families while remaining in compliance with the priorities of international development agencies and financial institutions”, despite the latter being “resolutely opposed to welfare state policies” (Zeiderman 2016, 111).

shows that strategic considerations shaped the conceptual framing of this development program, ultimately which helped it gain traction within the World Bank’s ecosystem of programs.

As summarized in a World Bank blog post, the program is structured into three distinct components (Sameh Wahba et al. 2018):

Technology: “Technology to locate, quantify, value, diagnose, and prescribe retrofit solutions for homes before the next disaster strikes”;

Technical Assistance: “Technical expertise to identify simple, affordable retrofitting solutions compatible with local practices and materials”;

Advisory Services: “Know-how to design policies and incentives”.

The first component, ‘**technology**’, concerns its mapping methodology. This branch of the program is coordinated by geospatial consultants directly employed by the World Bank, some of whom had previously served on its Geospatial Operational Support Team (GOST). Data collection across the different cities was primarily conducted under the guidance of the official program team. Most methodological development in triangulation, labelling, and machine learning was outsourced to Development Seed. This private geospatial company specializes in AI and data-driven tools for applications in the development and environmental sector, aiming to provide “Geospatial solutions and global insights for a complex and changing planet” (Development Seed 2025). The organization and workflow of the ‘technology component’ will be investigated in depth later.

The second component focuses on ‘**technical assistance**’ and is primarily managed by Build Change. As mentioned above, the NGO has engaged in housing retrofitting for years prior to the partnership with the World Bank and provided significant guidance for the GPRH’s approach to resilient housing. This technical assistance supports homeowners in improving their homes and provides guidelines for structural improvements, such as installing concrete floors or strengthening the building envelope. A stated reason for this approach is that many existing housing programs focus on “land tenure regularization” or “neighbourhood upgrading” but rarely support the construction process itself (Interview, 26.03.25, S. 16). Build Change also advocates for policy changes and offers custom tools that aim to foster government support for housing retrofitting.¹² An interviewee explained that much of Build Change’s work is policy-centred

¹² For instance, the organisation has published *The Build Change Guide to Resilient Housing: An Essential Handbook for Governments and Practitioners*, which consolidates its experiences with home improvement programs across 24 countries since 2004 (Build Change 2021). It has also recently developed the ‘Resilient Housing Ecosystem Assessment Tool (RHEAT™)’, a policy assessment tool aiming “to help countries, states,

because governments are often reluctant to support people in improving their own homes. In countries where policy forbids housing retrofits, like the Philippines, Build Change instead supports micro-financial institutions “so that they can do this on their own without the government participating” (Interview, 26.03.25, S. 15). While Build Change typically focuses on broader policy and strengthening individual housing units, the collaboration with the GPRH resulted in large-scale assessments of housing vulnerability, “without having to enter every house”(Interview, 26.03.25, S. 5). These housing assessments were important for negotiations with governments to show the potential benefit of retrofitting and induce related policy changes.

The third component of the GPRH consists of ‘**advisory services**’. This is the primary domain of the World Bank’s urban development specialist, and again subdivided into two branches: One of them focused on *housing policy* (“to help governments put resilience at the center of their housing subsidy efforts, and connect them to existing programs, such as slum upgrading, social cash transfers or property regularization”); the other focused on *private sector participation* (“to shine a light on opportunities for private sector participation in home improvement credit or insurance markets”)(Sameh Wahba et al. 2018). This consulting work on housing policy and finance of the GPRH thus continues the World Bank’s much longer engagement in the housing sector as part of its technical assistance programs (cf. Comerio 2025; Grubbauer and Escobar 2021). The program cooperates with governments to deliver subsidies and implement large-scale housing improvement projects, some of which are funded by World Bank loans. According to a leading official, the GPRH’s policy work resulted in significant changes in national housing policies, particularly in the countries where the collaboration was most extensive and could build on existing partnerships: Colombia, Mexico, and Indonesia.¹³ A team leader claimed that in these countries, housing policies have shifted toward improving existing units and that compliance with resilience standards has increased considerably, thanks to providing technical assistance to beneficiaries (Triveno Interview).

The interplay among these three components has shaped the GPRH’s operations and its approach. The geospatial housing assessments are an essential element of the program’s operations. The production of housing data establishes a baseline for political negotiations and helps convince local governments of the feasibility of its approach, and to address the qualitative housing deficit. These methods helped dispel misconceptions and misbeliefs about retrofitting

territories, cities, and communities identify key gaps and challenges as they work toward achieving resilient housing at scale”(Build Change 2025).

¹³ The GPRH was involved in multiple large-scale housing projects funded through the World Bank: the ‘Improving Housing Resilience’ Project in Mexico [P169278], the ‘Columbia Resilient and Inclusive Housing Project’ in Colombia [P172535], and the ‘National Affordable Housing Program’ in Indonesia [P154948].

policies, which policymakers deemed difficult to address. Common arguments against retrofitting interventions were that it was deemed “very risky to improve housing quality” as well as that structural engineer expertise seemed too expensive and complicated to organize (Interview, 04.06.25, S. 4). The program aimed to “remove the engineering question mark”, by developing cheaper assessment methods served to locate deficient houses for retrofitting and plan resource allocation (Interview, 04.06.25, S. 5). At the same time the methodologies also interest by local governments, as the fine-grained housing data produced by the program could also be used for other forms of governmental intervention.

Main Aims

Program members highlighted three general aims of the GPRH. These are not to be taken as definitive assessments of the program’s work and effects, but rather as a general orientation to understanding the rationales behind the program’s approach and methodology, and how these shaped the selection of the targeted settlements.

The first main aim concerned a paradigm shift from building new units to improving existing housing. A GPRH blog post portrays the underlying problem as follows: “Typically, housing budgets in developing countries focus on expanding new housing and mortgage markets for the middle class, rather than improving the poor majority’s existing housing” (Sameh Wahba et al. 2018). This was attributed to a lack of knowledge about retrofitting and the absence of “policies and incentives in place to start making homes safer at scale” (Sameh Wahba et al. 2018). The GPRH sought to change this reluctance to address substandard housing or the urban poor by persuading governments to address the *qualitative* rather than the *quantitative* housing deficit. Housing policy was described as an area “that is very ideological” but in which the program had successfully “made a point” with the work it has done (Interview, 04.06.25, S. 13). The ongoing partnership with Build Change was crucial in this regard, as the program could integrate the NGO’s existing expertise in engineering and housing improvements into its development projects.

The program’s second aim, one that the leader was particularly proud of, was having changed the narrative in disaster risk management from post-disaster reconstruction to their anticipatory approach of ‘Build Better Before’ (Interview, 04.06.25, S. 13). The program’s methodologies and policies aim to mitigate losses and damages in the next disaster, by identifying and preventively retrofitting homes that are deemed most at risk. It was admitted that substantial change was going to take more time as “the development industry” had invested so much money in the ‘Build Back Better’ agenda, even as this meant “essentially waiting for disaster to happen to build better” (Interview, 04.06.25, S. 13 - 14). This temporal shift towards anticipatory disaster management

closely aligns with the GPRH's overall framing and its technoscientific methods to predict which housing units are at risk.

A third aim of the program concerns its targeting of urban peripheries, most of which are built informally. Many of the World Bank's housing products primarily promote homeownership, focusing on subsidised mortgages with down payments. Such programs often require formal income, thereby barring informal workers from accessing housing subsidies, resulting in social exclusion. According to an interviewee, these eligibility criteria led to housing subsidies “essentially targeting the middle class” (int. Triveno). A related political problem the program wanted to address is that many governments did “not want to be perceived as ‘investing in slums’ or ‘promoters of informality’” (Sameh Wahba et al. 2018). On the other hand, many post-disaster reconstruction programs were often highly successful at targeting the most vulnerable. These experiences led the GPRH to focus on improving substandard housing in the name of disaster resilience, thereby strategically fusing these aims in its approach. This also led the program's mapping missions to primarily target disaster-prone urban peripheries.

A fourth aim concerns the legibility of the settlements and the ‘packaging’ of retrofitting. The program produces preliminary cadastre maps and accounts for how many housing units could benefit from housing retrofitting. This allows the ‘packaging’ of such interventions, the allocation of resources, and the estimation of costs (Interview, 20.01.22, S. 10). Some GPRH reports are entirely dedicated to estimating the costs of different retrofitting interventions, using these calculations to prove the overall economic feasibility of large-scale housing retrofitting. For example, one cross-country report aims “to lay the methodological foundations for a continuous and comparative analysis of the costs of housing improvement and construction, enabling countries to evaluate housing policies, programmes and financing instruments”.¹⁴ Establishing such baselines is a prerequisite for housing improvement projects to be ‘investable’ for donors such as the World Bank.

This section introduced the three components of the GPRH, which are embedded in the Bank's broader technical assistance to local governments. While the program's engagement and material impacts vary considerably across its sites, three overall aims can be identified: a shift from the quantitative to qualitative housing deficit; a temporal shift toward anticipatory interventions; the active targeting of disaster-prone urban peripheries, and finally to make low-

¹⁴ «su propósito es sentar las bases metodológicas para un análisis continuo y comparativo de los costos de mejoramiento y construcción de vivienda, que permita a los países evaluar políticas, programas e instrumentos de financiación de vivienda» (GPRH 2022a, 2)

income housing improvements ‘investable’. In line with my research questions and conceptual framework, the following chapters primarily focus on the GPRH's technology component by presenting its geospatial methods and to discuss how they relate to the program's other components and broader aims.

The ‘Information Gap’

The main gap addressed through the GPRH's ‘technology’ component is a perceived ‘information gap’ regarding the governance of informal settlements. In one of the main reports published by the GPRH the problem is worded as follows: “Construction and upgrading processes are restricted, as local governments do not want to be held accountable for human and material losses due to possible natural hazards in areas labelled as risk zones. *The main reason for this low political will to engage in retrofitting programs is limited information*” (GPRH 2021a, 97, my emphasis). By developing geospatial methods for large-scale housing assessments, the program promised to identify houses at risk that the governments seemed unable (or unwilling) to find on their own.

The GPRH's urban mapping was conceived as a necessary first step to support governments in implementing policy changes and designing interventions to address the qualitative housing deficit. Luis Triveno, the leader of the program, worded this fundamental epistemic problem in the following way: “They just could not identify it. So, locate it, quantify, and assess whether there was an opportunity here... The government just did not know” (Interview, 04.06.25, S. 4). According to an interviewee, many cities the program operated in “do not have any existing maps” which is why “the first initiative is to map the assets, producing just a map” (Interview, 10.03.25, S. 4). The legibility offered by these first assessments supported the broader reforms towards housing improvement pushed by the program: “we were able to tell governments: We can help you with the policy and we can help you find out at a very low cost where is your demand? Now, that is the moment when you started moving the needle” (Interview, 04.06.25, S. 5).

While the program typically presents the translation of housing data into appropriate political measures as a linear process, some interviewees also noted deeper political complexities related to the visualization of the qualitative housing deficit. Referencing the publication of statistics on the substandard housing stock in Colombia, a Build Change specialist claimed that the problem “was fairly known, but the scale and the masses... nobody had put it in those ugly terms” (Interview, 26.03.25, S. 7). He explained that the data produced by the GPRH was “able to convince politicians to make a lot of headway into reforming policy to start addressing these things” and that “once the problem was made clear, entities like the World Bank are not shy about

offering funding” (Interview, 26.03.25, S. 7). However, he also deemed the visibility to be a “double-edged sword” due to some government officials “freezing” when realizing the size of the problem, “and many people do not even want to look at it because it really is a big problem” (Interview, 26.03.25, S. 7).

Overcoming the perceived ‘lack of data’ on substandard housing is also considered important for financial institutions and insurance companies to operate in low-income housing markets. For example, one report states the importance of addressing “the information asymmetry that distances financial and insurance institutions from low-income households with housing deficits, who are excluded from formal credit markets” (Arrisueno and Triveno 2021, 57, my translation).¹⁵ The potential usefulness of this data to private actors is also highlighted in the GPRH’s main blog, where it is stated that “once insurance companies have the information they need to extend coverage, private lenders can offer loans for home improvements to creditworthy households, and local banks can feel confident in investing their resources in a larger housing subsidy program” (GPRH 2022b). The GPRH’s efforts to foster private sector participation were most advanced in countries such as Mexico and Colombia, where home improvement subsidies were linked with microloans and policy changes for “private capital mobilization” were implemented (Interview, 04.06.25, S. 17). This suggests that this data production and the resulting legibility are not only relevant for governance and housing retrofitting, but also for rendering substandard housing ‘investable’ and ‘insurable’.

A second potential use of this data is the creation of a preliminary cadastre. The cadastral survey is generally regarded as a fundamental for establishing formalized property regimes (Blomley 2003). The legibility facilitated by the GPRH’s methodology, particularly the ‘building footprints’ created from its drone images, could thus potentially be used to formalize the targeted settlements. In the interview, a leader of the program stated this as a possible application of this type of technology: “you could use this information to build a cadastre because of the precision... the cadastre is a starting point of the regularization because you identify what is there” (Interview, 04.06.25, s. 11-12). While he explained that governments deem this important, he also noted that regularization is not the program's primary focus. Partly because the systematic pursuit of property formalization could impede the implementation of housing retrofits. How exactly this tension was navigated in different contexts would have to be explored in more detail.

¹⁵ Original quote : “De ahí que resulte clave aprovechar la tecnología que se tiene a la mano, para acelerar procesos de levantamiento y puesta a disposición de información, para reducir así la asimetría informativa que aleja a las entidades financieras y de seguros de los hogares con déficit de vivienda y bajos ingresos, excluidos de los mercados formales de crédito” (Arrisueno and Triveno 2021, 57).

Nevertheless, the potential use of the GPRH’s methods and housing data for property regularizations was often emphasized in blogs and presentations, and, as discussed later, the program also piloted some functions pointing in this direction through its ‘housing portal’.

The construction of this ‘information gap’ reduces the thoroughly political problems of substandard housing, environmental risk, and informality to a simple lack of information. This gap is now presented as a technical, nonpolitical issue that can be addressed through the GPRH’s geospatial interventions. This reflects the observation of Tania Murray Li, that a fundamental feature of development programs is “the requirement to frame problems in terms amenable to technical solutions”, for which programmers “must screen out refractory processes to circumscribe an arena of intervention in which calculations can be applied” (Li 2007, 2).

From the perspective of the World Bank and local governments, the settlements targeted by the program constitute prime examples of ‘informational peripheries’. They are urban spaces “marked by both geographic and informational distance from the state” and include “subjects that are uncountable as well as territories that are unmappable” (Datta and Hoefsloot 2025c, 3). The core promise of the program's geospatial work is to thoroughly map these urban spaces from multiple perspectives, to render them amenable to analysis and interventions. Potential measures and questions derived from this housing data could include: “preventive resettlement; which buildings are eligible for subsidies; where to prioritize engineering efforts; where markets can solve the problem without public intervention” (Wahba 2018). While selectively targeting these ‘informational peripheries’ based on a ‘lack of data’, these operations mapped these settlements thoroughly from different angles, producing a vast volume of digital housing data (Figure 4).

TABLE A-1: Inventory of GRPH data as of June 2021
 Note that data continues to be collected within Colombia, among other countries.

	COLOMBIA	GHANA	GUATEMALA	INDONESIA	MEXICO	PARAGUAY	PERU	ST. LUCIA	ST. MAARTEN
Drone coverage (km ²)	40	11	4	80	31	17	20	8	28
Car distance (km, inc. overlap)	470	–	120	1,700	580	230	140	210	320
Panoramic images	411,910	–	62,036	587,880	337,601	121,368	107,337	109,200	168,691
Cube images	2,792,710	–	372,216	6,465,264	2,025,606	728,208	644,022	655,200	1,012,146
Street view labels	26,925	–	–	25,590	8,240	23,417	20,061	–	12,865
Rooftops	109,300	25,400	4,900	146,000	67,900	35,100	61,600	9,100	13,000

Figure 4: Inventory of housing data produced by the GPRH in different countries as of 2021.

‘Multi-View Urban Observation’

The use of geospatial technologies and machine learning for housing assessments sets it apart from many other housing initiatives and has been fundamental to the GPRH’s. The program’s use of technology is often emphasized discursively and visually in its public outreach media and was used as a selling point in negotiations with local governments. For example, one of the program’s earliest World Bank Blogs titled “Machine Learning Joins the Housing Revolution”¹⁶ proclaimed that it was “time we started systematically harnessing the power of machine learning in housing projects” (Antos and Luis Triveno 2018). Many presentations reproduce this narrative by first describing the impact of AI across different sectors, then making the case for using these technologies in the housing sector (Triveno Chan Jan 2023). This section focuses on the guiding principles of this technoscientific approach to housing resilience and describes how the GPRH frames the advantages of using these geospatial technologies for urban observation.

The program tends to highlight the advantages, rather than the limitations, of its technoscientific mode of seeing the city. On the landing page of its ‘housing portal’, the two main advantages of its approach to urban observation are stated to be: “Cost Efficiency and Social Distance: Our technology allows us to generate an unprecedented amount of data at a fraction of the cost in a fraction of the time. Gathering this data from cars and drone imagery allows us to maintain safe social distancing practices”(GPRH 2025). While framed in the context of COVID,¹⁷ this statement illustrates the program’s detached mode of data collection, which is much less open-ended than the house-by-house surveys it wants to overcome.

As stated above, the GPRH’s technology component aims to support national and local governments by using advanced technologies “to locate, quantify, value, diagnose, and prescribe retrofit solutions for homes before the next disaster strikes” (Sameh Wahba et al. 2018). The use of its technologies is mainly justified by emphasizing efficiency gains, their objectivity, and scalability, while still producing fine-grained assessments of housing units that include multiple relevant characteristics. The program tends to present its methodology as superior to traditional, manual survey methods. For example, it is stated in a blog that “finding homes that are good

¹⁶ The inverted version of this title (“Machine Learning Joins the Housing Revolution”) was later used for a podcast on the GPRH’s approach (World Bank 2019b).

¹⁷ A presentation specifically highlights the advantages of its methodology to be used in the context of the COVID-19 pandemic: “Through geospatial assessments, opportunities to reduce overcrowding and allow for social isolation and selfquarantining can be identified” continuing that reader may ask “Now you may well ask how governments will find these homes to target investments, particularly in the middle of a pandemic with social distancing requirements. That’s the good news. The methodology of the Global Program for Resilient Housing (GPRH) relies entirely on remote technology perfectly suited to current COVID-19 requirements. Images of the houses are captured from drones and car mounted cameras and then processed entirely in a home office”(Triveno et al., n.d.)

candidates for [...] retrofitting used to take months and dozens of surveyors” and that it “was an expensive endeavour to manually identify these high-risk buildings”(Antos and Luis Triveno 2018). According to the program, its geospatial methods and machine learning models are able to replace this bureaucratic labour, while still producing fine-grained housing data: “Using a car-mounted camera, a drone, a laptop, and advanced algorithms, it is possible to measure the height of each building, estimate the material of the roof, and gather information about the façade of the building” (Antos and Luis Triveno 2018).

The program’s reports and media are spiked metaphors that emphasize the power of its visual observation technologies. For example, the GPRH’s methods are imagined to “mimic the structural engineer’s expert eye” by combining three visual dimensions of “Satellite: (Roof material, Slope of the ground, Size of the rooftop), Drone: (Distance to neighbouring buildings, number of floors, Slope of the ground, Balcony detection)” as well as “Street View: (Window/wall ratio, Garages, Land Use) (World Bank 2017). Such visual metaphors are found throughout their documents, for example, another blog is titled “A Protective Eye on Bogotá”(World Bank 2021). This paints the program’s gaze as a kind of well-intentioned surveillance apparatus that monitors the targeted housing units in the name of resilience. The program sporadically admits that their assessments cannot completely replace the work of a seismic engineer, the algorithms only identify houses for further inspection in the field (e.g. GPRH 2019a, 44). However, the promise of automating the manual survey process and rapidly generating housing data is a driving rationale for the program and, arguably, also what makes local governments interested in these methods.

A further stated advantage of such technologies is their precision and objectivity. For example, the program describes itself as a “well-targeted and efficient housing program” (Triveno Chan Jan, Antos, and Rufianne n.d.). A GFDRR guidance note emphasized not only that using imagery was “about 70% cheaper than relying only on people for data collection”, but also that these methods “prevented human bias in data collection” (World Bank 2018b).¹⁸ Another report deems the advantages of Street View imagery to be that they provide “objective evidence of conditions in the field”, while stating that existing government data “can be messy (human error)” (GRSF 2021, 50). This corresponds to the belief that the program’s technoscientific instruments offer ‘mechanical objectivity’ (Daston and Galison 1992) and, by extension, a more objective assessment of urban

¹⁸ The World Bank’s Guidance note on Machine Learning largely reduces ethical questions to the discussion of bias and transparency, for example, by listing steps that can be taken to prevent bias when applying technologies. This positivist model of methodological reflection is committed to reducing ‘subjective’ preconceptions that could influence the data, thereby often pushing the use of such technologies, rather than conducting a broader analysis of how knowledge production is always situated within broader social, political, and economic contexts. (The World Bank, GFDRR 2018)

space than other modes of observation. This supports the claim of Thomas Cowan that the popularity of such devices for cadastral surveys “is anchored to drone and geospatial technology’s powerful claims to visual objectivity”(Cowan 2025b, 5).

Beyond imbuing the GPRH with an allure of high precision and objectivity, the program’s technoscientific methodology also achieves a higher resolution than many existing urban mapping methods, at least technically speaking. Drones and machine learning models have been mobilized for cadastral mapping and land digitalization in other contexts, such as the Svamitva scheme in India (Cowan 2025b, 2025a), and 360° street view imagery is increasingly used for the mapping of informal settlements (e.g. Cinnamon 2024). The combination of these technologies allows visual assessments of individual houses at an unprecedented level of detail. This multi-view observation allows the GPRH to capture information on the rooftop condition, building height, wall materials, and other criteria, such as the number of windows or building use. These technical possibilities shape which aspects of housing are processed and therefore rendered legible, governable, and actionable by the program. These technical capacities define the program’s operation and condition the flexibility of its methods for different applications, which will be examined in depth in later chapters.

Perhaps the best illustration of the program’s technoscientific approach to urban observation is the retrospective provided in a World Bank blog post titled ‘*Jacob’s Dream: Improvising Disaster Risk Management Using Visual Clues in the Age of AI and Machine Learning*’(GPRH 2024a). The title references the book ‘*Looking at Cities*’, by US urban planner Allan B. Jacobs’, which aims to “show how professional planners and others in urban environments can use field observation as an important diagnostic tool“ (Jacobs 1985, 5). The program took up his idea of ‘urban clues’, which he defined as “something that can be seen that tells the observer something he or she desires to know. Clues help the observer understand the nature of the urban environment being examined” (Jacobs 1985, 30).

Situating its own methods within the same tradition of urban observation, the GPRH proclaims that :

“Four decades later, Jacobs’ framework remains relevant, even as the tools we use to study and visualize cities have transformed. We no longer require a notebook and comfortable shoes to understand an urban environment. Today, *from a continent away*, we can see [...] whether building foundations are cracking, roads are paved, and sidewalks navigable for wheelchairs”(GPRH 2024a, my emphasis).

The blog then outlines the advantages of its own use of technoscientific tools to identify such ‘urban clues’ in an automated matter:

“Recent technological advancements enable us to efficiently review images, identify urban clues, and reveal spatial patterns across an entire neighborhood or city. By applying machine learning algorithms to high-resolution imagery taken above the city (aerial imagery) and at ground level (Street View imagery), we can make *comprehensive, multi-view urban observations from the sky and street*. The resulting georeferenced datasets and accompanying visualizations hold enormous potential to help create resilient, healthy communities. That includes unprecedented opportunities for spatial planning, disaster and climate risk management and reduction» (GPRH 2024a, my emphasis).

This ambitious vision demonstrates the GPRH’s embrace of technoscientific modes of seeing the city in the name of resilience. Jacobs’ preferred mode of urban observation was walking as he argued that “[t]he speed of other modes makes it difficult to see and explore details” (Jacobs 1985, 12). The program, however, depicts its distant, fast-paced, and scalable mode of observation not as an impediment to careful observation, but rather as a strength, proudly highlighting that its assessments may well be conducted ‘from a continent away’.

‘Build Better Before’

A core element of the GPRH’s approach is that the program advocates for a temporal shift in disaster risk management according to which interventions occur *ex ante*, before the next disaster strikes. Build Change CEO Elizabeth Hausler also stated at the founding event that “an emphasis on prevention rather than reactive response is overdue on the global development agenda given the increasing strength and frequency of natural disasters” (Build Change 2018). The advantages of its anticipatory mode of intervention are frequently compared with those focused on ‘Build Back Better’, an agenda that emphasizes disaster reconstruction and providing support for ‘recovery spaces’ (Borie and Fraser 2023). The GPRH, on the other hand, emphasizes that the predictions from its technoscientific methods will allow governments to ‘Build Better Before’, promising to prevent the losses and damage that are usually only addressed after the fact. In line with work on future geographies, this section examines “the forms of authority and expertise that enable certain futures to appear, gain and retain presence” and how the GPRH’s future-oriented framing of its interventions “is used to demand, justify and legitimate certain forms of action to secure life” (Anderson 2010, 787).

The primary justification for the GPRH’s shift towards anticipatory disaster governance is the humanitarian imperative to save lives. Many of the program’s presentations include statistics on

earthquake deaths from natural disasters, suggesting that poor-quality housing must be treated as “a matter of life and death” (Figure 5) (Wahba 2018, 20). This framing legitimizes the employment of predictive mapping methods, promising to guide precise interventions into vulnerable urban spaces to prevent such losses. As explained by an interviewee, housing retrofitting is not about mitigating damage completely but about granting families some additional seconds to escape their homes before they collapse (Interview, 04.06.25, S. 12). Some presentations make this preventive aim of its mapping abundantly clear: “We can find homes that are death traps – one at a time – before it’s too late” (Antos and Luis Triveno 2018, fig. 1). This framing of the GPRH’s anticipatory approach reflects a general observation made by Zeiderman that following logics of risk and security, ‘life’ is being managed “not as a valuable resource to be cultivated, improved, or promoted, but as a vulnerable possession at risk of being harmed or taken away” (Zeiderman 2016, 60).



Figure 5: Slide from a presentation on the GPRH, stating the importance of addressing substandard housing through housing policies and preventive housing retrofitting. The calculations illustrate the framing of the GPRH's anticipatory approach to 'resilient housing' and 'Building Better Before' (Wahba 2018, 20)

The origin of this anticipatory mode of intervention was attributed to a 7.1 magnitude earthquake in Mexico in September 2017. The event caused more than 40 buildings to collapse, one of which was a school, leading to the death of 19 children and seven adults (World Bank 2021). As explained by a program leader, some images taken before the earthquake were shown to structural engineers, who could quickly identify the type of buildings likely to “pancake”: “you could see on Google Street View that the school was obviously a high-risk building... they call it a soft story: the first floor is quite open and not structurally sound, and then the top is quite heavy” (Interview, 23.04.25, S. 3). This led the founding members to think that, given suitable urban

imagery was available, machine learning could be used to visually identify seismically vulnerable structures and predict the likelihood of buildings to collapse.

Another central trope used by the program's campaigns for anticipation is the endangered space of the home, represented in images or narrated through stories of preventable tragedies. For example, the GPRH podcast titled "There is no Place like home" begins by asking the listener to think about their childhood and their home, stating that "Homes are the center pieces of our lives, but also where disaster often strikes" (GPRH 2019b). The podcast ends with the programmatic statement that "this is really just about saving lives. One house, one village, one region at a time. Before it is too late!" (GPRH 2019b). The GPRH's main target of intervention and space at risk is not the city at large, but individual homes. Besides serving as justification for its preventive approach, this shift in scale stems from the disaggregation provided by its mapping techniques. This imperative to protect life from future harm is consistent with the modes of anticipatory governance typical for risk management. The GPRH reframes disaster events such as earthquakes "not solely as emergencies requiring response, but as catastrophes that could have been foreseen and either prepared for or prevented" (Zeiderman 2016, 68).

The GPRH's preventive interventions are not only framed as humanitarian but also justified through cost-benefit calculations regarding economic growth and development goals. The underlying rationale is that "natural disasters can erase decades of achievements in poverty reduction in minutes or seconds" (Wahba, 2018). The GPRH's approach is thus also presented as economically viable: "if countries can #BuildBetterBefore and strengthen substandard homes now, governments will save untold costs of reconstruction and debt financing later" (Build Change 2018). An official infographic titled "Resilient Housing, Resilient Cities" includes multiple statistics on the various losses caused by natural disasters, indicating some of the calculations at play: "Earthquakes cause 44,585 deaths on average per year", leading to "human capital losses", "well-being losses", but also "asset losses of US 327 billion on average per year" (World Bank 2017). Further economic calculations result in statements such as "The loss of income in a country for an occupied person dead in an earthquake: > 50x GDP per capita", or that "Reconstruction costs > 4x what prevention costs" (World Bank 2017). In a presentation given a year later, presumably to government officials, some of these same statements are reproduced with even higher numbers: "Governments understand! Reconstruction costs more than 10 times what prevention costs. The Bill is paid by the government" (Triveno Chan Jan, Antos, and Terraza 2018). These calculations imply that costs can be saved by saving lives, illustrating an observation made by Ben Anderson that "anticipatory action has emerged in a situation where it is precisely

the contingency of life that is the occasion of threat and opportunity, danger and profit” (Anderson 2010, 782).

This future-oriented communication strategy invokes a sense of urgency to act in the present. For example, “unless we start doing things differently, more families will continue building in dangerous areas”(Triveno Chan Jan, Antos, and Terraza 2018). In a podcast, the urgency is made very explicit: “when disaster strikes, every second counts, every moment spent deciding how to respond, instead of jumping into action, impacts how many lives are saved“ (GPRH 2024b).

These emotional narratives and statistical calculations through which the program invokes the drastic effects of looming natural disasters indicate “how the experience of the future relates to the materiality of the medium through which it is made present” (Anderson 2010, 793). Whereas the GPRH’s public outreach media make use of emotional narratives, its policy reports rely on statistical calculations and highlight the cost-efficiency of its approach. The general strategy across these different media is to frame the GPRH’s approach as a moral duty, common-sensical, and economically viable: The overlap between humanitarian, economic, and other goals aligns with the aim of many urban resilience interventions to tap into a ‘resilience dividend’. The Overseas Development Institute has recently worked with the World Bank in defining three dimensions of this dividend: “saving lives and avoiding losses, unlocking economic potential, and the cobenefits of disaster risk management investments” (Webber, Leitner, and Sheppard 2021, 356).

In line with the program's overall anticipatory framing, its methodology calculates futures using technoscientific tools and methods. In the technical reports produced by the GPRH, these generally take the form of risk maps and algorithmic predictions. In pilot projects in Mexico, geospatial mapping identified unreinforced housing units, enabling the program to estimate “potential losses in case of earthquakes” in the area of interest. It is then claimed that these losses could be halved through targeted retrofitting efforts for the houses deemed most at risk. The report concludes “that simple and small investments can, at the same time, improve the quality of life of families and significantly reduce the expected losses in the event of a disaster” (GPRH 2019a, 7). The *predictive* mode of its mapping efforts, as well as the *preventive* mode of subsequent retrofitting interventions, are thus essential parts of this overall shift towards anticipation.

The ability to prevent such losses seemingly hinges on taming uncertainties by estimating and locating urban risks. According to the GPRH report on Colombia, overcoming the information gap is a fundamental condition for such calculations: “The lack of data precludes an appropriate risk

assessment” and that governments “do not have technical instruments that quantitatively assess risk” (GPRH 2021a, 97). The GPRH offers exactly such ‘technical instruments’ that enable the identification of risk zones and the calculation of approximate future damages. The program thereby fulfils the function of rendering uncertain and dangerous urban futures calculable and actionable. This corresponds to the observation made by Zeiderman that such technical diagnoses are part of the “ongoing effort to render the uncertain future an object of official decision-making in the present” (2016, 76f).

The fact that the frequencies of natural disasters will only increase due to climate change is cited as an additional long-term justification for the program’s efforts. In a recent YouTube video on the GPRH’s disaster preparedness, titled “New Normal” it is claimed that “we can no longer afford to treat a crisis as a surprise because it’s really no longer a question of if but when” (GPRH 2024b). The video concludes that “being prepared with better, more resilient housing [is] the best strategy to provide a safer, healthier future“ (GPRH 2024b). These urgent calls to build housing resilience assume a planetary state of exception in which disasters are ubiquitous threats, preparedness is unquestioned, and there is no time to decide how to respond. This corresponds to the paradigm of ‘Anthropocene Urbanism’ and how its focus on building resilience “centres and normalizes risk and prioritizes the ability to adapt to inevitable catastrophe” (Derickson 2018, 431). As development actors prescribe and implement ‘urban resilience’ in cities around the world, they increasingly adopt models of governance whose “forward-looking anticipatory logic marks a reorientation of the temporalities of knowledge” (Derickson 2018, 426). The predictive analytics used by the GPRH clearly show that such logics of anticipation and preparedness also shape the governance of informal housing.

This section has discussed the fundamental imperative of anticipation in the GPRH’s framing of its approach to resilient housing and its predictive mapping methods. The program’s methods aim to predict which houses are likely to collapse and estimate hypothetical losses and damage. This extends disaster risk calculations into the future and uses these numbers to urge action to mitigate this projected damage. The GPRH is not alone in enacting these shifts towards anticipatory governance. The GFDRR strategy for 2021-2025, for example, “simply and plainly” states that “a country which does not invest in disaster risk management will see its hard-won development gains wiped away in seconds when disasters strike” (GFDRR 2021c, 7). Such future-oriented calculations and rationales flank the program’s geospatial interventions and flank its policy reforms, thereby rendering “the uncertain future an object of official decision-making in the present” (Zeiderman 2016, 67).

A program leader stated that he was particularly proud that the GPRH “changed the narrative a little bit from Building Back Better” (Interview, 04.06.25, S. 13). Part of the reason for this success is the program’s future-oriented media production combined with its technoscientific methods for predictive slum mapping, which promise to tame uncertain urban futures and thereby legitimize anticipatory action in the present. Critical disaster studies have recently examined the politics of knowledge around competing visions of how to ‘Build Back Better’ in ‘disaster recovery spaces’ (Borie and Fraser 2023). The GPRH’s shift towards anticipatory disaster risk management shifts attention to how resilient futures are imagined, whose expertise is mobilized, and what interventions are justified through this temporal shift.

The GPRH’s Mode of Operation

The GPRH is part of the Global Facility for Disaster Reduction and Recovery (GFDRR), a global partnership hosted at the World Bank, whose objective is ‘mainstreaming’ disaster risk management and ‘scaling up’ resilience. The program thus operates within the World Bank’s institutional framework and uses the financial, administrative, and operational systems of its technical assistance partnerships. This institutional position enables the GPRH’s global mobility and fundamentally shapes the organization and geography of its mapping missions.

This chapter examines how the GPRH operates through the Bank’s technical assistance projects and showcases its engagements across different urban settings. The examination of the institutional factors that shape its multi-sited mode of operation identifies the structural ‘conditions of possibility’ of its geospatial experiments. The chapter also provides insights into the diverse contexts in which the program was active, showcasing how this mobility led to a variety of unique partnerships that fostered the re-application of its geospatial methodology.

Technical Assistance

The GPRH operates as part of the World Bank’s partnerships with client countries that request some technical support. The World Bank generally defines its Technical Assistance programs as “the transfer of skills and knowledge for developmental purposes” for “supporting project preparation and implementation” (World Bank 1996). The guiding framework for this country-based development model is the ‘Country Partnership Framework’, which defines a development

strategy for each country in accordance with the Bank's development agenda and national development priorities (World Bank 2025).

This resulted in unique development partnerships through which the GPRH's approach and methodology were continuously re-adapted to different urban environments and local policy contexts. A senior development specialist explained: "every time we are working on a new country, you inherit a policy and operational partnership that has been there for many years" and that "without the country identifying what they need, we do not do anything" (Interview, 27.1.25, S. 6f). This corresponds to the observation by the World Bank scholar Pereira that "client states are not passive entities, since there are always processes of negotiation, adaptation, filtering, and translation of local norms, and actions prescribed by the Bank" (Pereira 2022, 373).

The coupling of technical assistance to the World Bank's lending operations also conditions the countries to follow certain development models and implement related reforms. The usual sequence is that technical assistance, consisting of advisory and analytics services, serves as preparation for loans, aiming to create suitable conditions for investment (Interview, 20.01.22, S. 6). Sometimes, individual grants for technical assistance are also given as 'quick fixes' to maximize or amplify the impact of ongoing investments. As the countries risk being denied access to the capital channelled through the Bank, this puts considerable pressure on client governments to adopt the recommended 'technical' changes. In the words of a Bank development specialist: "if we do not try to find a technical solution that complies with our standards, reasonably, we are not going to be able to lend money to you"(Interview, 20.01.22, S. 6). These conditionalities do not only concern the loans directly facilitated by the World Bank's lending operations. Because the World Bank also acts as "a funnel for international donors" for many different types of development projects, this also concerns access to many other sources of development funding (Interview, 27.03.25, S. 16). The fear of being denied access to the enormous sums of capital channelled through the Bank, gives the World Bank considerable leverage to push specific development and governance models through its conditionalities (Bigger and Webber 2021).

The GPRH's position at the World Bank is a fundamental condition for its flexible engagement across different cities and lends authority to the knowledge produced. Opportunities arising from partnerships with certain countries determined where the program became active: "the reason we were in a country would be because the loan is happening, or about to happen... And we have been requested by the leader of the loan to help out" (Interview, 23.04.25, S. 6). In certain countries, the program could leverage their position to develop projects at the municipal scale: "the World Bank had ongoing engagement with the national government and through them we got

the enabling environment to work with city governments too” (Interview, 04.06.25, S. 16). When ongoing projects were regarded as impactful, the program sometimes actively reached out to donors to extend their operations: “We go to a donor and say ‘look, we have this opportunity. We are working in the city, and we could do much more if we would just have this, you know, one or two million or whatever”” (Interview, 20.01.22, S. 6 - 7).

After the first pilot projects to prove the feasibility of its approach, the GPRH formalized its methodology for replication. According to one member, this enabled the program to “go to market” within the World Bank’s ecosystem of programs, where it met high demand from client countries, leading to new partnership opportunities (Interview, 20.01.22, S. 9). An interviewee attributed the interest to the cheaper cost of retrofitting projects in comparison to building new housing: “their response was very, very strong. They wanted this type of project, because it’s cheaper... it is a fraction of the cost for them” (Interview, 20.01.22, S. 9). Further selling point of the program were the short ‘delivery time’ of home improvement projects in comparison to new construction projects, “so they could actually deliver something within their political terms”, as well as that it reduced the contingent liability of governments for disasters by mitigating losses and damages (Interview, 20.01.22, S. 9). This appeal of the GPRH’s approach to decision makers was an important factor that made client governments interested in collaborating with the program and support its operations.

The support from local governments was not just a formal prerequisite for the program’s operation but also lent legitimacy to data collection in different cities. A member involved in the mapping process explained that “you definitely need buy-in from the local governments to pull off these types of projects, because without that, you are just another organization that’s there... Good luck trying to get access to fields that you need to fly from...” (Interview, 05.04.25, S. 12). The governments also provided personnel who accompanied data collection, for example coordinators who communicated the purpose of mapping to locals. It was further stated that governments “can also help arrange security if necessary, depending on what types of environments that you are operating in” (Interview, 05.04.25, S. 12). This shaped social encounters with locals and made the program’s operational procedure much smoother: “If I had worked for a private company flying these areas... no doubt you would have way more sceptical people” (Interview, 05.04.25, S. 21). Government support was therefore essential to facilitating the GPRH’s access to the ‘field’ and granted legitimacy to data collection.

The process through which partnerships with the GPRH came to fruition emerged from the interplay between its own research agenda and the strategic interests of local governments. Some engagements also arose from relatively spontaneous opportunities. For example, some of the

GPRH's mapping operations were embedded into other World Bank programs or funded by third-party donors or trust funds. The institutional constellation at each site influenced the approach taken there. This hybrid, networked mode of operation is characteristic of many of the Bank's global programs and partnerships. While this fragmentation can obscure the relations between the GPRH's geographically dispersed projects, this mode of engagement offers considerable flexibility for global operations.

'Areas of Interest'

The GPRH's operations strategically targeted substandard housing, mostly informal settlements, based on a broad morphological typology. Shatkin et al. define such a framing of informality as being "based on assessments of the visually 'unplanned' character of settlements that are often rooted in unspoken aesthetic judgements" (Shatkin, Braswell, and Martinus 2023, 947). In line with the World Bank's country partnership framework, it was primarily the local governments who selected 'areas of interest' and defined the specifications for this mapping work.

To select areas of interest on the national and municipal level, the GPR first scouted "dense settlements that we felt were relevant for collecting data" that governments were particularly interested in (Interview, 10.03.25, S. 7). This could be due to them being in known zones of environmental risks, or just because there was a general "lack of data" about certain urban areas. In meetings between the GPRH and government officials, the settlements were then prioritized according to practical considerations and the budget and time available (Interview, 05.04.25, S. 10). One interviewee explained that "oftentimes it would be an area where the government was interested in investing in. So, they were going to have a project or build new infrastructure there. They needed the information for something" (Interview, 23.04.25, S. 14). The "beneficiary selection" for subsequent retrofitting and technical assistance by Build Change was done accordingly: "those are decision made by the government, informed by the technical matters that we provide for them" (Interview, 26.03.25, S. 12).

While the program's methods were developed to assess substandard housing in zones of environmental risk, in some cases the program also applied its methods to formal settlements and even entire cities, such as Padang in Indonesia: "We captured a wide range of houses, because it helps with the machine learning training stock... you try to capture variations" (Interview, 10.03.25, S. 7). While the strategic government considerations shaping this selection process in specific countries could not be explored in detail, a common element is that the program targets low-income informal settlements. This overlaps with recent attempts of the World Bank to advance its 'financial inclusion' agenda through the expansion of microfinance

schemes by “explicitly targeting lowest-income groups and were explicitly wrapped in a ‘pro-poor’ discourse”(Grubbauer and Escobar 2021, 536).

Geospatial Experimentation

Alongside the GPRH’s multi-sited operation across Latin America, the Caribbean, and Indonesia, the technicians experimentally adapted its methodology to different contexts. Based on the interests of local governments and its own research agenda, its geospatial methods were tested across a variety of urban environments to develop new applications for its technologies and workflows. This ongoing geospatial experimentation became a driving force behind the program, leading it to expand its technical repertoire into different sectors such as property valuation, taxation, and even road safety. This mode of operation reflects the World Bank’s power as a global knowledge institution, which “should be understood as a productive agent maintained through its interactions in multiple sites” (Goldman 2005, 12).

Most of the GPRH’s applications were pilots, and the outcomes of its partnerships in different sites were not predetermined but emerged from situated experimentation. According to a senior geospatial specialist at the GFDRR, described the GPRH as one of the “high innovation units at the Bank” whose operations require “a bit of creativity”(Interview, 27.03.25, S. 12). Whereas many larger Bank programs “want to operate in a low-risk environment” such geospatial programs generally “work in fields we know have a lot of potential” (Interview, 27.03.25, S. 12). Many new applications arose from technicians experimenting with the housing data already available. For example, a technician explained that “we have definitely tried some algorithms that nobody requested, but maybe we thought: ‘Oh, there might be potential here’” (Interview, 23.04.25, S. 6). One of the applications resulting from this was using algorithms to identify street signs and logos to estimate business activity. These quotes illustrate the research-driven mode of engagement of the program, which actively seeks new applications.

This overall mode of the GPRH’s multi-sited operations and experimentation with different fields of application is described by an interviewee in the following way: “We have sort of branched and zigzagged and applied the technology to various types of projects in various sectors. Part of it is money, and part is also demand. So, if we have somebody who's leading the project who approaches us and says: ‘Hey, I would like help with X, Y, and Z’... then we try to figure out how we can use the technology and the methodology to help them...” (Interview, 23.04.25, S. 6). Such adaptations could emerge from requests by governments or particular challenges. During the COVID pandemic, for example, the program was approached by statistical agencies from different

countries that asked whether they could design an algorithm to predict poverty in specific areas from the outside (Interview, 04.06.25, S. 8).

Many interviewees discussed the changing circumstances and environments between different mapping sites and how they shaped the mapping missions. For example, one technician explained that “when you do a different location, then all of a sudden, again, architecture and surroundings and everything and socioeconomic factors all change, but then also the things you care about because they are at risk of something else... of a different natural disaster” (Interview, 25.02.25, S. 4 - 5). This comparative mode of knowledge production was often emphasized as a unique strength of the program’s mode of operation. Many projects deliberately sought to target multiple sites within the same country or directly recommended replicating the methodology in different environments to produce new insights (e.g. GPRH 2019a, 41).

The GPRH’s mode of operation, therefore, corresponds to the insight of Sophie Wakefield that under the paradigm of implementing urban resilience, cities are increasingly seen as sites “where uncertain futures are unfolding and laboratories in which experimental practices and technologies of governance are being tested out” (Wakefield 2021, 335). Promising to provide municipal governments with monitoring technologies and fine-grained housing data for disaster preparedness, the GPRH actively embraces such ‘situated experiments’ in different urban environments.

Multi-sited Operations

A driving factor of the GPRH were its mobile operation across multiple cities in Latin America, the Caribbean, and Indonesia [Figure 6]. The World Bank's partnerships with client countries provided the program with considerable resources and the ability to operate globally. While the context of every such partnership was unique, this enabled the program to experiment with its methodology across different urban settings and for different ends. This section will portray the range of these engagements, briefly showcasing the local contexts in which the program operated and how these shaped the reapplication of its geospatial methods. This will not allow for a contextual understanding of each of these interventions but will instead showcase the GPRH’s dynamic mode of operation. A core purpose of these brief portraits is to showcase the re-application of its geospatial methods across different sites.

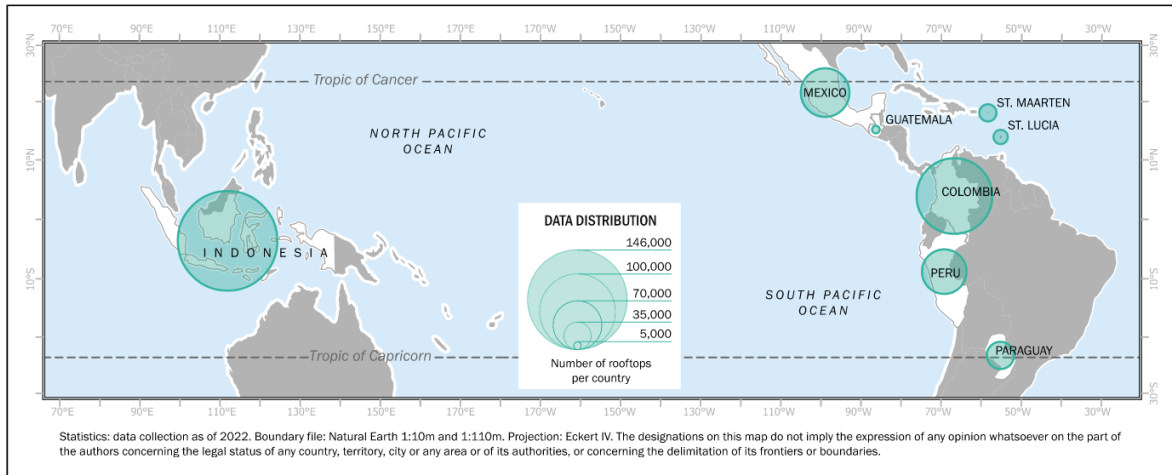


Figure 6: The GPRH's countries of engagement and the scale of its data collection as of 2022. Besides collecting a significant volume of data, this geography of engagement also enabled adaptation and experimentation with its methodology (Gosling-Goldsmith et al. 2024, fig. 1).

Guatemala

The first two applications of the GPRH's methodology occurred in Bogotá and Guatemala City as early as 2017. These early mapping missions occurred before the program's formal establishment but already involved the same World Bank consultants who would later form the heart of the GPRH. Compared to the elaborate algorithms and diverse applications of later engagements, the methodology was still in its early stages, and the urban imagery was primarily used to locate structurally weak 'soft-story' buildings" (Build Change 2018).

The program did not map the entire city but focused on the districts in Mixco, Villanueva, and El Porvenir. The program mapped an area of approximately 100 hectares, scanned 4,967 homes, and algorithmically detected 503 possible soft stories with 85% accuracy. This early pilot of the GPRH's methodology focused on identifying 'soft stories'. This included detecting houses that were "at least two stories high", had "unconfined rooftops" as well as houses that were "built on a slope steeper than 15 degree" (Antos 2017, 18). The assessment procedure was described by using the medical metaphor of the 'Triage' from emergency services: "Similar to a doctor using machine learning to identify cancer, structural engineers can rely on machine learning to flag homes that are possible 'soft-story' and need further inspection" (Build Change 2018). Their own version of a "Housing Triage" was described as "the process of sorting housing units based on their need for immediate intervention and its associated economic and technical feasibility" (Antos 2017, 4).

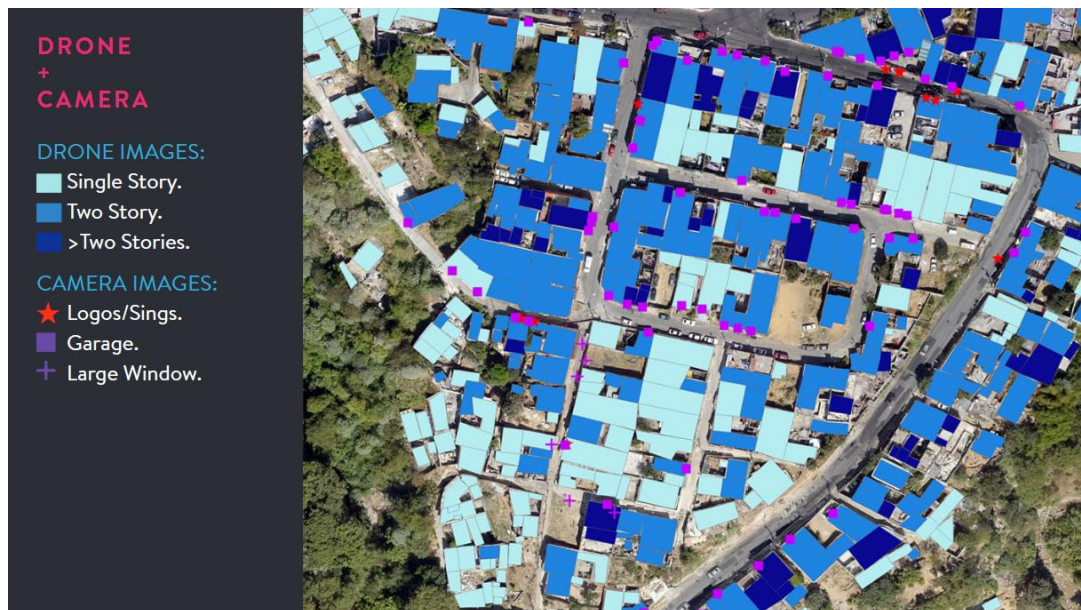


Figure 7: Risk Map of a District in Guatemala City (Triveno Chan Jan n.d., 35)

A presentation on the GPRH’s engagement in Guatemala concluded that the projects’ methods “can reduce the number of units by 90% so engineers in the field only have to visit a fraction of the housing stock”(Antos 2017, 21). It also stated that the program is “now working to link the results to retrofitting projects targeted investments and loans”(Antos 2017).

Showcasing the ongoing experimentation with these geospatial technologies, some of the same housing data was later used for other purposes. A presentation shows that the data produced were used to locate homes with dirt floors, of which 50’625 were identified (Triveno Chan Jan, Antos, and Rufianne n.d.). The imagery collected in Guatemala was also used to develop new machine learning models, such as an algorithm to identify logo signs as proxy for business activity (Antos and Luis Triveno 2018). A technician recalled that the idea for this application “just popped into my head” because she kept seeing such logos and signs when driving around with the camera and thought that “we could detect these and then use it as a proxy for economic activity within these neighborhoods” (*Interview, 23.04.25, S. 6*).

The program’s technical methodology was relatively simple when first applied in Guatemala. The algorithmic analysis of the Street View imagery was limited to identifying logos/signs, garages, and large windows and not yet capable of detecting materials, building conditions, and structural reinforcements of the housing envelope. While the technical methodology was still in its infancy, the potential ascribed to such urban mapping was already considerable. A presentation slide on the Guatemala project suggests the wide range of uses the housing data could be used for: “Resilient Housing Projects; Developing new Markets for home insurance; Reforming housing subsidy or cash-transfer schemes; Connecting Housing subsidies with microloans; Promoting

expansion in consolidated areas and the creation of new housing for rental; Regularization of informal constructions”(Antos 2017, 22). This first urban experiment in Guatemala City was not yet as thoroughly documented as subsequent engagements; however, it already showcases some of the program's central aims, its experimental mode of operation, and hints at later uses of its methodology.

Mexico

One of the GPRH's main countries of engagement is Mexico. Some of its first pilot projects took place in two cities of the Istmo de Tehuantepec Region in Oaxaca: Salina Cruz and Juchitán de Zaragoza. These engagements were part of the World Bank's 'Improving Housing Resilience' (P169278) project, which provided technical assistance to the national government. The program's operations in Mexico were also among the first to be systematically documented in a synthesis report on '*Improving Housing Resilience*' (GPRH 2019a).

The World Bank project provides technical assistance to the National Housing Commission (CONAVI) and the Ministry of Agrarian, Land and Urban Development (SEDATU). It aims to increase resilience by “(a) improving the targeting of housing subsidies; (b) strengthening municipal urban management and (c) improving the design and implementation of CONAVI's existing home improvement subsidy scheme (GPRH 2019a, 5). Illustrating the combined approach of the GPRH's three components in Mexico, large sections of the synthesis report concern 'technical assistance' and 'policy advocacy'. For example, an extensive review of Mexico's existing housing policies and programs, “to identify what works and what doesn't work in public housing assistance for the poor and most vulnerable” (GPRH 2019a, 6). A section contributed by Build Change engineers includes lists of different types of retrofitting interventions with their average costs (GPRH 2019a, 38). In line with the overarching aims of the GPRH, the report recommends “the reduction in the qualitative deficit”; “a focus on the more vulnerable” through “new geographic priorities and improved operational rules”; and finally that “resilience needs to become a central part of the Government's housing policies and programs” (GPRH 2019a, 13f). This reflects the core aim of the program to assist local governments in shifting policies towards housing improvements and targeting the urban poor.

Focusing on the 'technology' component, I will primarily examine the geospatial mapping conducted through the two pilot projects in Oaxaca. The stated aim of the urban mapping was “to assess the vulnerabilities of the housing stock and identify opportunities for simple, affordable and effective housing retrofit”(GPRH 2019a, 6). The pilots in Mexico adapted and expanded the technical procedures developed elsewhere, to test whether “the methodology could be scaled up

and replicated in other parts of the country, particularly regions exposed to high natural disaster and climate risks”(GPRH 2019a, 6).

As described in the report, the piloted methodology “combines the application of geospatial technology to characterize the housing stock and assess its levels of vulnerability, analysis of census data and hazard risk maps, and selective qualitative assessments to provide a picture of the reconstruction and retrofit needs in the area with an unprecedented level of detail”(GPRH 2019a, 6f). The imagery produced in Oaxaca encompassed 30km² of land by drone and 580km of road by Street View cameras. This housing data was then used to perform detailed engineering assessments to identify options for structural strengthening. As a final step, “Probabilistic risk models were used to evaluate the efficacy of allocating more public funds in an ‘area of interest’ in Oaxaca”(GPRH 2019a, 7).

The housing assessments calculated that 18% of housing units were unreinforced or semi-reinforced and that “targeted retrofit interventions” of the located homes could reduce the estimated potential losses in case of an earthquake by half (GPRH 2019a, 7). In line with the program’s approach of ‘Build Better Before’ and anticipatory governance, it is recommended “that simple and small investments can, at the same time, improve the quality of life of families and significantly reduce the expected losses in the event of a disaster”(GPRH 2019a, 7).

These geospatial experiments were integrated with broader municipal reform and capacity-building efforts. For example, the report diagnoses a “resource gap” concerning “a lack of available data and analysis about the housing stock” as well as the need “to tailor housing assistance mechanisms to the needs of the most vulnerable population and expand access to flexible financial services to those most in need” (GPRH 2019a, 7–8). Many recommendations relate to the geospatial capacities of the local governments: “Adopt a robust and simple methodology to assess the vulnerability of the housing stock”(GPRH 2019a, 7) or “improve the use of granular data of the housing sector” (GPRH 2019a, 26). It concludes that existing housing programs “can benefit from a geospatial information system that informs decisions about home and urban improvements, as well as about reconstruction, resettlement and formalization” (GPRH 2019a, 30). This demonstrates that the pilots primarily serve to test the feasibility of rapid housing assessments, while recommending the broader integration of such geospatial methods into urban governance.

The stated use of these geospatial capacities to inform the targeting of housing programs and policies. For example, the report recommends that new housing programs in Mexico “improve the use of granular data of the housing sector”, and it is deemed crucial “to identify the characteristics

of the housing stock to inform decisions about the allocation of resources through different instruments and target audiences, with a focus on the most vulnerable” (GPRH 2019a, 26). Showcasing the different spatial scales at which the GPRH operates in Mexico, the report identifies priorities at three spatial levels: The national, neighbourhood, and housing unit levels:

- At the *national level*, it recommends to “prioritize municipalities with a high percentage of their population living in hazard prone land” (GPRH 2019a, 34).
- At the *neighbourhood level*, it is stated that drone imagery “could provide policymakers with the type of detailed information they need to improve the effectiveness of their policies and programs” (GPRH 2019a, 34).
- At the *housing unit level*, the multi-view imagery produced by the GPRH’s methodology “provides information about not only the location, dimension, quality, and material of each building but also information on the front of the building (use, wall material, features)”(GPRH 2019a, 34).

The report thus concludes that “With the rich household level database derived from Street View and drone imagery, home improvement programs can better target certain types of at-risk homes“(GPRH 2019a, 34). Even if such fine-grained housing data are only collected in relatively small ‘areas of interest’, the pilot projects in Oaxaca primarily served to convince governments that such targeting could be feasible. The GPRH’s methodology and geospatial systems facilitate a rescaling of housing policies, which enables governments to prioritize interventions down to “the scale of the neighborhood and the individual property”(Zeiderman 2016, 74). Another point recommends “promoting financial inclusion by designing savings, credit and insurance instruments that suit the needs of the different population segments “(GPRH 2019a, 7). This shows how the GPRH’s housing assessments were coupled to a disaggregation of housing policies while also recommending the expansion of corresponding (micro-)financial products.

The conclusions of the synthesis report illustrate well that the targeted settlements were not merely seen as spaces of improvement but also became urban testbeds for the program’s geospatial technologies. The two pilot projects were seen as confirmation that the “methodology for the assessment of the housing stock proved to be affordable, reliable, and scalable”(GPRH 2019a, 8). It was emphasized that similar “fieldwork” could be replicated in other Mexican states designated as priority areas for national housing programs, particularly those with poor populations. It was also noted that the targeting of the two cities “provided an opportunity to test the bank’s methodology on different environments“(GPRH 2019a, 41), thereby illustrating how the GPRH’s multi-sited operation also shapes its geospatial knowledge production.

The report explicitly recommends the ‘scaling up’ and replication of the GPRH’s technical methodology, stating that “[t]he next step is the proof of concept of the feasibility of applying the vulnerability assessment methodology at scale, extending the scope to a greater area”(GPRH 2019a, 41). It also suggested prioritizing municipalities “with distinct geographical, sociocultural and economic conditions, so that the model can be used for multiple hazards and locations”(GPRH 2019a, 41). Pointing to the use of the same methods for other fields of urban governance, the report also stated that “the methodology and technological tools applied can be used for other objectives such as property valuation and tax collection” thereby “better linking housing, urban governance, and disaster risk management policies (GPRH 2019a, 41).

The GFDRR annual report of 2023 summarizes the long-term engagement in Mexico, by stating that the GPRH “helped the country team support the government to achieve two challenging objectives: reaching the most vulnerable population while mobilizing private capital”(GFDRR 2023, 26). Besides strengthening housing standards this involved “the rationalization of housing subsidy schemes by connecting them to other financing sources across the board with a deliberate focus on targeting areas with the highest vulnerability and housing needs”(GFDRR 2023, 26). According to the report, the project “facilitated the mobilization of \$1.93 billion in loans for new and improved housing”(GFDRR 2023, 26).

The GPRH’s pilot projects in Oaxaca were the first operations to be thoroughly integrated with comprehensive technical assistance and policy advocacy. The learnings from these pilots were also summarized and circulated through World Bank blogs, helping the program gain further traction. Whereas earlier mapping efforts were limited in scope, the work in Mexico was systematically documented. The mapping of these two ‘areas of interest’ supported the re-prioritization of subsidies towards informal workers and the low-income housing sector, while aiming to scale up such assessments by building the government’s geospatial capacities. The housing assessments supported the recommended policy changes by estimating retrofitting costs and imbuing housing programs with a sense of precision.

Monika Grubbauer and Luisa Escobar have shown that the World Bank’s engagement in Mexico’s housing sector is characterized by policy experimentation. They especially note “the revival of programmes for the self-organised production of housing coupled with the roll-out of new financial instruments very much in line with the World Bank’s financial inclusion agenda” (Grubbauer and Escobar 2021, 536). This involves housing microfinance schemes which “were explicitly targeting lowest-income groups and were explicitly wrapped in a ‘pro-poor’ discourse”(Grubbauer and Escobar 2021, 536). The GPRH’s operations in Mexico illustrate that such experimentation can be coupled to geospatial experiments to support such targeting. A

GPRH team leader stated that Mexico was a country where the GPRH “completely switched the whole thing... They said not only we want to go from quantitative to qualitative... we want to go to the poorest of the poor” (Interview, 04.06.25, S. 6).

Colombia

The GPRH’s operations in Colombia were characterized by a close cooperation with national housing agencies and extensive policy work. The program’s engagements in Colombia were part of the ‘Colombia Resilient and Inclusive Housing Project’, a 136.7\$ million Bank operation of which 100 million \$ were financed by the World Bank’s IBRD. The program’s consultants were actively involved in the design of housing policy schemes, including the large-scale national housing program, Casa Digna Vida Digna, initiated in 2018. A leader of the GPRH suggested that the shift towards housing improvement and the targeting of housing subsidies was especially successful there (Interview, 04.06.25, S. 6).

The GPRH’s engagement is documented in the report ‘Striking a Balance: Toward a Comprehensive Housing Policy for a Post-COVID Colombia’(GPRH 2021a). Similar to the work in Mexico, this report focuses on reviewing national housing policies and programs, contributions from World Bank urban specialists, and government partners. This work corresponds to the GPRH’s overall aims and presents the Casa Digna Vida Digna program “as a novel paradigm for the country, one that should be further developed in the coming years to advance a more comprehensive housing policy that will continue to reduce the qualitative housing deficit and lead to the elimination of extreme poverty” (GPRH 2021a, 1).

The GPRH conducted ‘housing quality assessments’ in three different cities in Colombia, Cartegna, Soledad, and Neiva. These provincial capitals were selected because they were identified as “areas with the highest housing deficit”, based on “data availability and population”, and due to them facing “different major natural risk and maintains zoning restrictions for retrofitting processes” (GPRH 2021a, 22). The mapping in these sites was largely done according to the procedures tested in previous mapping interventions. As part of the larger cooperation with Colombia’s Ministry of Housing, the GPRH used its methods to generate a database of physical characteristics in the three targeted municipalities.

This data collection was conducted in a complementary manner and systematically combined with a ‘deprivation analysis’ based on existing census data. A report highlights that “the additional information from the GPRH helps characterize housing needs in deprived neighborhoods and estimate the cost of integrated retrofitting interventions”(GPRH 2021b, 70). It was mentioned that the GPRH did not conduct full mapping of the cities, but only assessed “units in prioritized blocks

that were assessed by the program constitute a representative sample for the ones that are to be intervened upon in the rest of the city”(GPRH 2021b, 70). This shows how the geospatial data produced by the GPRH is integrated into the existing census system of the Colombian government, complementing it with additional information on the physical housing quality. These two levels of information are contrasted in the following way: “The World Bank’s analysis is based on image recognition, inferring household conditions by how the unit looks from the outside,” while the census data “is collected by directly surveying the families and inquiring about their socioeconomic and housing conditions”(GPRH 2021b, 72). Although the key promise of the GPRH is to overcome such manual, more qualitative survey methods, in reality, they are always grafted onto historical state information systems.

The main aims of the GPRH’s geospatial data in Colombia were the prioritization of “intervention zones for retrofitting projects” (GPRH 2021a, 133) and the estimation of retrofitting costs (GPRH 2021b, 71). As in other cases the government support aimed at achieving the “right policy mix” to shift existing programs towards the qualitative housing deficit and targeting low-income populations, “who often reside in substandard homes on hazard-prone land and have limited access to credit or insurance” (GFDRR 2023, 123). As elsewhere, these efforts were flanked by an expansion of related financial mechanisms and credit schemes, serving to explore “the potential of expanding the home improvement microfinance market” (GFDRR 2023, 26).

An innovative aspect of GPRH’s engagement in Colombia was its support for the National Planning Department in developing an indicator to measure urban vulnerability at the Block level (Grupo Banco Mundial, DNP Colombia 2021). The underlying calculations relied on existing census data on the block and district level and produced indices for urban governance; it therefore employed a different methodology than the production of housing data for individual housing units and was thus not further analysed. As Zeiderman indicates, Bogotá has emerged as a ‘model city’ for urban risk management (Zeiderman 2016, 194). This is mentioned by the GPRH in a blog post, that “due to the strength of the Bogotá model, the team shared the data with the Bogotá government’s Geographic Information System team for further validation and inclusion into a neighbourhood vulnerability index they are creating” (Antos and Triveno 2023). The program’s broad engagement in Bogotá can therefore be seen as a larger effort to mainstream its own forms of risk management and create further visibility for its approach.

Arguably, the most interesting experimental application of the GPRH’s methodology in Colombia was conducted in Bogotá, where “a model was built to correlate the characteristics derived from machine learning with property values” (Antos and Luis Triveno 2018). The inspiration for this application was ‘Zillow’, a US platform that provides public property estimates by using the

'Zestimate', an automated valuation model (AVM) (Zillow 2025). A presentation states three reasons for "why we need Zillow estimates for the developing world", naming "Property tax", "Housing", and "Large opportunities for credit and insurance market to grow if granular data on assets and exposure is available"(Triveno and Antos 2019, 7). A second slide states "why don't we have Zillow estimates in the developing world?" answering by stating that "50% of the properties are informal", "Cadasters & census are outdated or nonexistent", and that "Data on transactions is expensive and inaccurate" (Triveno and Antos 2019, 8). The program again poses the 'lack of data' as the underlying problem to be addressed, implicitly assuming that housing problems could be rectified if cadastral systems were improved, and in extension, if property values were publicly available for private actors to serve these segments.

Given that housing data is available, the methods to create property valuation on a large scale are fairly simple and use the same attributes as the resilience assessments. The first step is "to conduct field surveys and evaluate some prices for different types of housing", while the second step requires "price identification from multiple sources" such as local real estate portals (Triveno and Antos 2019, 46f). With this information machine learning models can be trained on the few existing estimations in the 'field' and then use similarities within the available housing characteristics to scale them up to the entire 'area of interest'. While the initial calculations are fairly simple and mainly based on drone data, a presentation also stated that the program is "developing more sophisticated models that use more intensively attributes extracted from Street View" for the government of Colombia (Triveno and Antos 2019, 51). This "mass property valuation" uses the housing data and physical characteristics predicted by the program's machine learning models and trains another model on top of them, now trained to estimate property values. The outcome of this method are maps visualizing the estimated property values of each house of the mapped districts, as shown in Figure 8, or filtered maps showing the distribution of houses "estimated to be unaffordable" (valued above \$18'000) (Triveno Chan Jan, Antos, and Rufianne n.d., 39f).

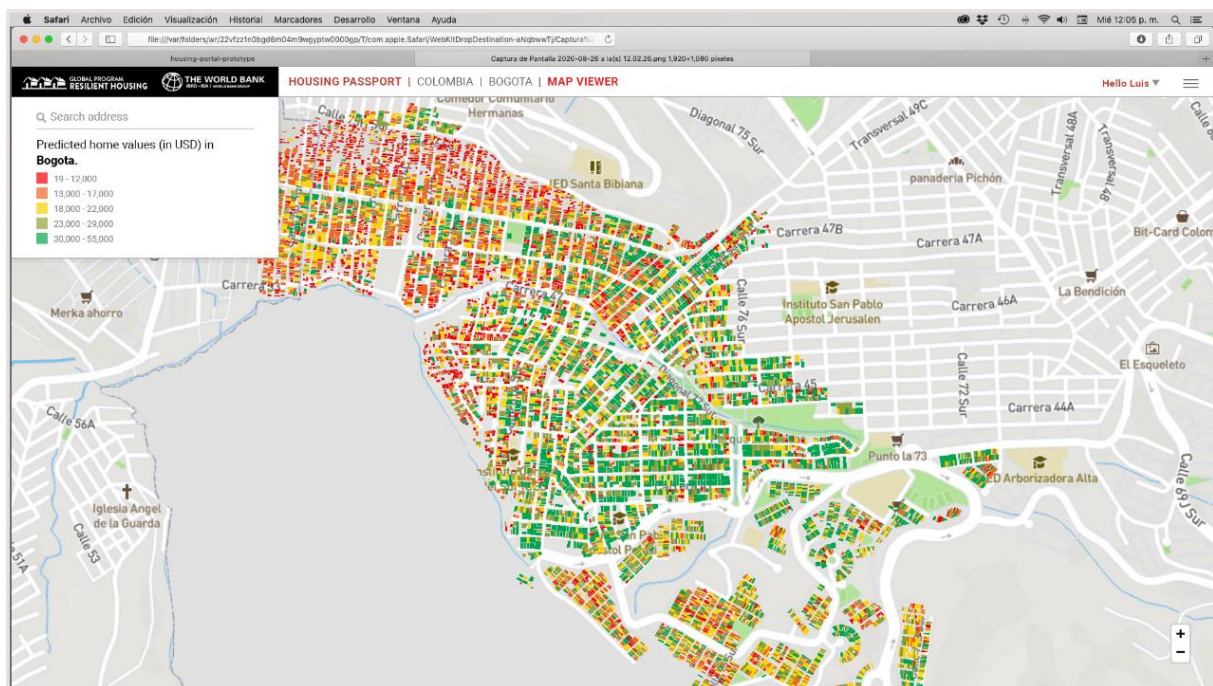


Figure 8: Home Values in Bogotá predicted by the GPRH based on urban imagery (Triveno Chan Jan et al., n.d., 40).

For this application, the GPRH estimates property values using ‘black boxed’ machine learning models trained on urban imagery. This assumes, and performs, a correlation between the ‘look’ of these houses and their market value. This raises questions about the effects of such assessments based almost entirely on visible aesthetic qualities, and the measures derived from them. Hypothetically, a cheap cosmetic upgrade would disproportionately inflate the estimated value, and housing that ‘looks’ improper (to the algorithm) could be devalued even further. By virtually facilitating the economic legibility of entire neighbourhoods but digitally constructs these houses as bounded, ownable, and potentially tradable assets with market value (Birch and Ward 2022; cf. Cowan 2025a). Like other forms of spatial value assessments, such as algorithmic judgments and classifications, are “not only diagnostic, but prescriptive” (Safransky 2020, 207). Through their use by different state and non-state actors, such technoscientific valuations shape the urban landscape in unequal ways.

Peru

Another site the GPRH was active in was the capital of Peru, Lima, with mapping efforts particularly targeting the historical Breña district. Data collection in Lima was conducted in a manner similar to that at the program's previous sites. Exemplifying the program's experimental mode of operation, the housing data was again used for different purposes here. For instance, for locating overcrowding homes at the block level in Lima, presumably resulting from overlapping

its cadastre maps with existing census data (Triveno Chan Jan, Antos, and Rufianne n.d.). Another use was the classification of structures by age, presumably using clues from their building facade, which concluded that at least 4000 buildings of the Breña district were built between 1941 and 1973 (Triveno Chan Jan, Antos, and Rufianne n.d.). Yet another different use, this time related to the municipal tax revenue system is showcased by maps that locate “units that have not paid property taxes in Lima” in which case 4,532 buildings were identified for the fiscal year 2019 (Triveno Chan Jan, Antos, and Rufianne n.d., 37f). The loss of tax revenue was estimated to amount to around 4.3 million USD (Triveno Chan Jan, Antos, and Rufianne n.d., 41f).

The GPRH’s engagement in Lima intersected with previous World Bank programs and projects in Lima, showcasing an instance where its institutional position to opportunities for new applications of its methodology. The City Resilience Program (CRP), briefly introduced in the literature review section, had also targeted the city and supported project preparation for the World Bank’s ‘National Urban Cadaster and Municipal Support Project in Peru’ initiated in 2020. This project is funded through a IBRD loan of US\$ 50 million¹⁹ and aims to “improve the coverage of urban cadaster services in selected municipalities to enhance local government capacities for revenue generation and urban management” (World Bank 2019a).

As explained by a project brief, the CRP supported “a review of the gaps in local property tax revenue and an assessment of hazard risks in the municipality of Breña”(CRP 2020). This support involved “the use of drone and Street View imagery, machine learning and municipal taxpayer information to build a database to improve municipal property tax assessment and collection” (CRP 2020). This database builds on characteristics of the housing stock in the district, “particularly linked to the physical characteristics and potential vulnerabilities to the impact of natural hazards, and its valuation will be complemented through the complete updating and deployment of the district’s urban cadaster”(CRP 2020).

¹⁹ The International Bank for Reconstruction and Development (IBRD) is the lending-oriented branch of the World Bank Group.

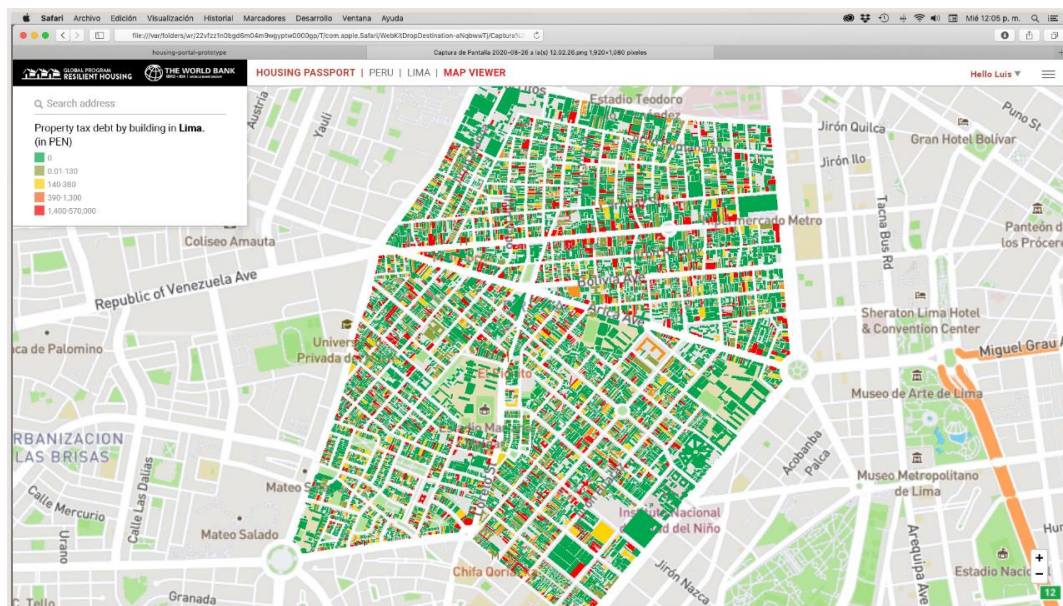


Figure 9: Property tax debt by building in Lima's Breña district (Triveno Chan Jan, Antos, and Rufianne n.d., 42)

As the Peruvian case shows, the GPRH's methods and cadastral maps proved highly adaptable to diverse contexts and purposes. In this case, the building characteristics identified could be directly integrated into another World Bank project focused on property tax collection and “helping urban municipalities strengthen their capacity to generate revenue” (CRP 2020). The case also shows the World Bank's privileged position as a facilitator of international funding from various sources. While mainly funded through a World Bank loan, the project was further supported by 5 million Swiss francs granted by the Swiss Secretariat for Economic Affairs (SECO) to fund “further cadaster improvements as well as to the improvement of municipal urban management and revenue generation capabilities”(CRP 2020).

The project indicates the foundational status of the urban cadastre for urban governance, whose efficacy nonetheless relies on measurement techniques to capture the spaces under consideration. A World Bank press release deems the cadastre “a crucial tool to enable municipalities to identify the properties in their jurisdiction and their characteristics” and states that the project aims to “develop a national data platform to consolidate urban cadaster data” (World Bank 2020). Similarly hinting at the use of such multi-purpose mapping methods as tools for assetization as the application for property valuation, it also states that “Identifying the uses, value, location and characteristics of urban assets will empower local governments to improve urban planning, service delivery and infrastructure, as well as to prevent and respond to disasters, at the same time it increases their capacity to generate their own resources” (World Bank 2020).

When asked about this specific application of the methodology for tax collection, a leading technician saw the partnerships as an opportunity; “we saw that there was really low collection

of property taxes in the area. And so, we thought: ‘Why don't we see if we can use that?’ (Interview, 23.04.25, S. 18). She also explained that “it was very much a proof of concept” and that she was “not sure that the local government had the capacity to continue with it... but they were very involved, and it created some buzz and interest in it” (Interview, 23.04.25, S. 18). Indicative of the program’s multi-sited circulation of such methods, she further mentioned that they are going to use the same methods for a pilot project in the Philippines, where the Peru example would be used to showcase the potential of these methods.

Small Island Development States: Dominica / St. Lucia / Sint Maarten

Multiple GPRH mapping missions took place in Small Island Developing States (SIDS) in the Caribbean, including St. Lucia, Dominica, and Sint Maarten. SIDS are generally deemed some of the most vulnerable sites to climate change, particularly regarding their vulnerability to floods and hurricanes, emerging as key sites of disaster risk management efforts by different international development actors (e.g. Borie and Fraser 2023). This section describes the program’s engagements on these islands and how its approach was re-adapted to different contexts.

The GPRH’s engagements across the Caribbean are relatively well documented in a technical guidance note, which synthesizes practical experiences from mapping across different islands (GPRH 2022). The introduction states that “SIDS are ideal locations to apply the GPRH methodology” due to two reasons. The first are resource challenges “that restrict the generation of detailed, updated datasets, resulting in reliance on customary datasets or limited use of incomplete or obsolete datasets”(GPRH 2022c, 8). The report further claims that small areas but dense population “makes them a suitable size for collecting data using drones and street view cameras” (GPRH 2022c, 8–9). Such statements illustrate that “historical development of incomplete and territorialised information infrastructures” shape the emergence of information peripheries (Datta and Hoefsloot 2025b, 242). This section examines how the GPRH targeted these islands as laboratories for its methods, serving as “experimental testbeds of new smart technologies for visualisation, mapping and urban governance”(Datta and Hoefsloot 2025a, 3).



Figure 10: Hurricane Damage Prediction in St. Lucia by the GPRH (Wahba 2018, 28).

Rooftop Inventories

One of the earliest GPRH operations in the Caribbean involved using drones and Street View imagery to create ‘rooftop inventories’ in Dominica and St. Lucia. This aimed to predict the vulnerability of rooftops to strong wind events to help prioritize roof repairs and prepare for Hurricane season [Figure 10]. The relevant characteristics for this process were age, height, and roof slant, all of which determine the structural stability of rooftops.²⁰ The parallel data collection on different islands also promised comparative insights: “Once we collect all this data, we will be using it and comparing it to some of the data that has been collected in Dominica, which is a pre and post disaster damage assessment. So we will be learning from their experience and trying to predict the vulnerability and strength of the roof tops here in Saint Lucia” (Gov. of St. Lucia 2018).

In St. Lucia, the GPRH created a geospatial housing inventory of over 10,000 buildings. The mapping included characteristics such as “the shape, material, and condition of their rooftops”, which were used “to estimate the potential housing damages and losses from a Category-5 hurricane” (Antos and Luis Triveno 2018). Similar to its previous work in earthquake-prone areas, the application of GPRH’s geospatial methods in the Caribbean was legitimized by the cost-efficiency of preventing hurricane damage before the disaster. Citing the estimated damages caused by Hurricane Maria in 2017, the program states in a blog post that its aim in St. Lucia was

²⁰ The classification models used to determine rooftop quality employed some pro-bono work of external machine learning consultants who created a convolutional neural network (CNN) model for the drone image data (Christopher Williams 2019).

“to prove how easily such costs could be avoided” (Antos and Luis Triveno 2018). The data production was also seen as relevant for other actors: “By automatically generating household-level information, governments, homeowners, and the private sector are given the baseline information they need to make decisions” (Antos and Luis Triveno 2018).

An original application of the GPRH’s methodology in St. Lucia was the assessment of the vulnerability of housing rooftops to hurricanes. This involved using drone-generated 3D models to differentiate between different roof shapes [Figure 11]. Drawing on engineering studies on disaster vulnerability, the program used these data to estimate the vulnerability of specific housing types to hurricanes. The result was a dataset on housing vulnerability to a category five hurricane. While such innovations arise from place-specific considerations and environmental risks, they have also expanded the GPRH's methodological repertoire over time.

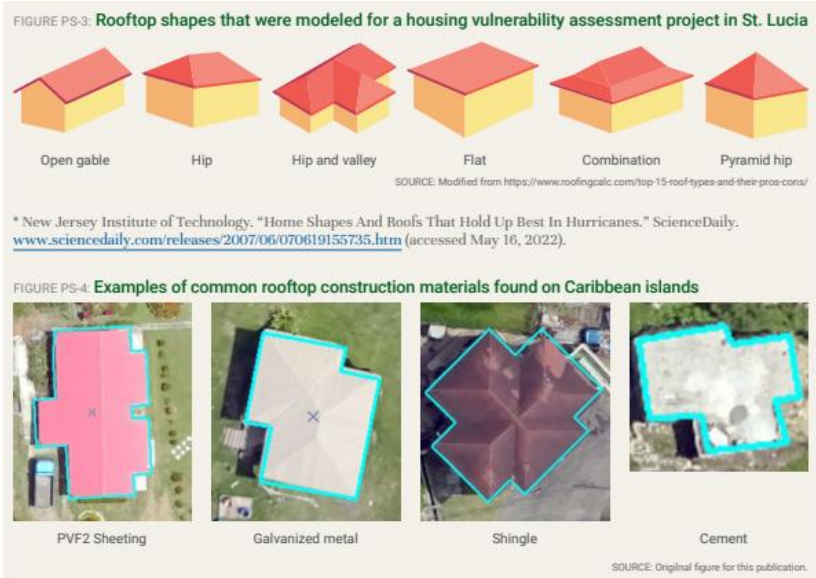


Figure 11: Typology of Rooftop shapes in St. Lucia. This method of identifying rooftop shapes emerged from its engagement in the Caribbean, where rooftops were in focus due to hurricane risk (GPRH 2022c, 37).

Rapid Housing Sector Assessment in Sint Maarten

Two years after Hurricane Irma had devastated Sint Maarten in 2017, a team of World Bank urban specialists conducted a ‘Rapid Housing Sector Diagnostic’ on the island (RHSA 2020). This was the first comprehensive assessment of the housing sector undertaken since the hurricane and was understood “as the start of a dialogue on housing with the Sint Maarten government, and as a foundation for the Bank to develop a longer-term engagement in the sector” (RHSA 2020, 6). The assessment was organized through the Sint Maarten Recovery, Reconstruction, and Resilience Trust Fund, but the GPRH contributed a drone and street view analysis (DSVA). The study concluded that 90% of the total building stock in Sint Maarten is residential, and that this category is in poorer condition than other categories. As stated in the report, data collection “begins by

outlining an area of interest based on the client’s needs and wishes, for instance concentrating on disaster-prone or informal living areas”(RHSA 2020, 32). The outcome of this assessment was an inventory of houses by number of stories, roof condition, and roof material [Figure 12].



Figure 12: Roof Conditions in Belvedere, Sint Maarten (RHSA 2020, 42)

The report also recommends that housing data collection across the island should be improved. It is stated that the currently available “data on the housing sector is limited and derived from disparate sources” and that “a set of standard housing indicators” should be implemented “to track the status of the housing sector in Sint Maarten” (RHSA 2020, 91). As in earlier sites, the use of GPRH’s methodology was deemed appropriate for addressing these historical data gaps by producing new housing data. Some of the recommendations derived from these housing assessments were that the government should “provide targeted assistance to low-income and vulnerable households”, by providing financing for roof repairs and incremental housing improvements, as well as setting up pilot projects for informal settlement upgrading (RHSA 2020, 19). The modular integration of the geospatial housing assessments into this broader report on Sint Maarten’s housing sector demonstrates how the GPRH’s methodology for housing assessments was also replicated and embedded into different World Bank projects.

A central concern of the housing sector assessments in Sint Maarten concerned “the increase of informal settlements” (RHSA 2020, 36). Consequently, one use of the GPRH’s methodology focused on locating informal housing. The DSVAs located 10 informal areas across the island and estimated that 15% of the residential units are informal (RHSA 2020, 14). One application in Philipsburg was to “locate slums”, which estimated that “8% of the housing stock is located in slums” and that “52% of these units could benefit from roof retrofitting” (Triveno Chan Jan, Antos, and Rufianne n.d., 19f). The program’s methodology was also used to locate backyard homes in

Philipsburg, the capital of Sint Maarten, estimating that 6% of the housing stock has backyard dwellings (Triveno Chan Jan, Antos, and Rufianne n.d., 27). This place-specific form of housing occurs when landowners lease land or huts in their backyards, which are often built illegally and in poor condition (RHSA 2020, 37). Such housing units are usually challenging to detect, but the application of the GPRH's drone imagery facilitated their legibility across the island. While I could not determine how such specific applications were designed, or how the resulting spatial data was ultimately used, these smaller applications demonstrate the program's flexibility across a range of urban settings and its adaptation to place-specific government interests.

Similar 'Rapid Housing Sector Assessments' were conducted for other Caribbean islands as part of subsequent projects managed by the GFDRR. For example, the 'Resilient Housing and Affordability Assessment projects' (2020-2022) in Saint Vincent and the Grenadines, the Dominican Republic, and Saint Lucia, aimed at "the development of rapid housing sector assessments as well as the subsequent integration of resilient housing policy topics into the governments' agendas"(GFDRR 2024a). A central component of the project is the adaptation of the GPRH's methodology to conduct a 'Housing Stock Resilience Analysis'. The outputs of this expanded engagement on SIDS included: high-resolution aerial and street photography; a new geospatial database of building characteristics; and a new web-based data visualization tool (GFDRR 2020).

Capturing Housing Data

The practical experiences with planning and capturing housing data across the Caribbean were documented in an extensive technical guideline on data collection. The stated objective of the report is "to provide an overview of best practices and considerations for SIDS to reference when capturing housing data using the GPRH methodology." (GPRH 2022c, 12). The audience for this report is World Bank officials and other development actors interested in assessing housing stock in SIDS or elsewhere.

The advantage of the program's technoscientific mode to urban observation for efficient and socially distant data collection was emphasized. The report notes that SIDS governments "all seem to share an eagerness to adopt new technology that would improve operational efficiency" (GPRH 2022c, 10). It goes on to state that the "minimization of personal contact can also reduce some potential biases arising from human-derived assessments" and is particularly "beneficial in areas with security concerns" (GPRH 2022c, 10). Such challenges could arise from place-specific challenges to data collection. For example, a consultant mentioned that people in Sint Maarten "were super sceptical" and asked him about what they were doing with the camera, "they

wanted much more privacy, whereas in other places we went, they didn't care at all" (Interview, 23.04.25, S. 19).

The report notes the multi-purpose nature of such fine-grained housing data, stating that "there are numerous potential Housing Portal applications from workflow-derived data including: cadaster updating, regularization, and mass valuation" (GPRH 2022c, 10). It also mentions that the GPRH methodology "is flexible enough to deliver datasets with spatial accuracies that accommodate the specific registry needs of citizens within that jurisdiction" and could therefore be used by "taxation departments" as well as supporting "land tenure security" (GPRH 2022c, 10). To my knowledge, these applications were not implemented in the Caribbean, but the data collected readily lend themselves to the application of other algorithms.

These operations across the Caribbean demonstrate how the GPRH's approach was adapted to different contexts and how this 'island hopping' led to new applications of its methodology. Limited in scope, the data collection mainly served to demonstrate the use of such methods "to obtain crucial housing data quickly and cost-effectively" (GFDRR 2023, 17). According to the GFDRR's annual report, the assessments "convinced the governments of Dominica and St. Lucia to proceed with a comprehensive building data set inventory", which "will serve as a baseline for countries' resilience projects, including the deployment of asset management systems and housing investments programs" (GFDRR 2023, 17). A team leader of the program confirmed to me that the program had a significant impact on the housing sectors of SIDS, despite their much smaller population compared to other countries of engagement (Interview, 04.06.25, S. 9).

In earlier engagements, the program had concentrated on identifying 'soft stories' in earthquake zones. In the hurricane-prone Caribbean, however, its primary focus shifted towards assessing rooftop stability and supporting governments in locating informal housing, particularly the place-specific form of backyard dwellings. These mapping experiments across different islands yielded key lessons for the GPRH, ranging from new methodological procedures to practical experience in planning and organizing mapping missions across diverse settings.

Indonesia

Indonesia has become one of the GPRH's most important countries of engagement. This is partly due to one of the GPRH's leaders being transferred to Indonesia, which enabled the program to establish extensive partnerships with the government. Indonesia already had extensive home improvement programs before the GPRH's engagement in the country. Hence, the GPRH focused on increasing compliance with resilience standards by incorporating technical assistance and quality assurance mechanisms into existing programs (Interview, 04.06.25, S. 6). The GPRH's

work was part of a \$450 million project in support of one of the largest home improvement programs globally, the *Bantuan Stimulan Perumahan Swadaya*. The GFDRR annual report highlighted that resilience standards could be improved, and 238'037 new households could be targeted, while also shifting the allocation of the \$1.28 billion already spent by the government on the program (GFDRR Annual Rep 23, 66).

The GPRH's mapping in Indonesia was the most extensive of all countries of engagement and primarily focused on the city of Padang on Sumatra, which had been hit by a 7.6 magnitude earthquake in 2009 and had already been addressed by Build Change. The city was fully mapped by both drones and Street View, encompassing all housing types. This was possible due to some of the data collection being outsourced to local companies (Interview, 10.03.25, S. 11). The urban mapping covered an area of 90 km², encompassing 146'000 buildings (Triveno Chan Jan, Antos, and Rufianne n.d.).²¹ The use of different machine learning models was also among the most elaborate and included most of the building characteristics that had first been tested at other sites in the program.

Although the largest-scale mapping efforts of the GPRH were conducted in Indonesia, there is almost no documentation of the program's activities there, aside from a presentation and a few scattered references. This can be partly explained by the fact that this engagement could build on the methods established and tested in other sites. One innovative use of the program's methods particular to the coastal city of Padang was identifying buildings that were located within 20 meters of the coastline (Triveno Chan Jan, Antos, and Rufianne n.d., 8).

The complete mapping of Padang, a city of around 1 million people, proves that the program's methods can now facilitate the legibility of entire cities from the sky and on the street [Figure 13]. It also shows that the GPRH's methodology is not limited to informal settlements but can be applied on a large scale and a wide variety of building typologies. The lack of documentation on the case, unfortunately, does not allow more insight into how this almost complete legibility of the city from above and the street has shaped its urban governance.

²¹ The mapping produced 587'880 panoramic photos, 6'465'264 raw cube photos, ~1,700 km of roads, which 23TB of raw data (Triveno Chan Jan, Antos, and Rufianne n.d., 18).



Figure 13: Key Characteristics collected by the program in the city of Padang (Triveno Chan Jan, Antos, and Rufianne n.d., 10).

‘Urban Clues for Road Safety’

Perhaps the most unique cases of the GPRH’s geospatial experimentation involved applying the program’s methods to assess road safety in Bogotá and Padang. In this collaboration with the Global Road Safety Partnership (GRSF), the GPRH diverged far beyond its initial field of resilient housing. The case shows that the GPRH’s main effect lies in its production of geospatial knowledge, namely in its use of technologies and in the development of methods to capture urban space and analyse it using machine learning algorithms.

The GRSF is a multi-donor trust fund hosted at the World Bank that aims to support “efforts in low and middle-income countries to halve their road traffic fatalities and serious injuries” (GRSF 2025). Usually, the GRSF conducts traffic safety research or publishes road safety guidelines; however, the GPRH’s methodology opened new avenues for collaboration between the two World Bank entities. The collaboration resulted in the technical report *Detecting Urban Clues for Road Safety: Leveraging Big Data and Machine Learning* (GRSF 2021). The main outcome of this collaboration was the development of an “automated road safety scan system” which “detects road characteristics from street-level images and provides a road safety prediction for each segment analyzed”(GRSF 2022). Similar to its procedure at other sites, the program captures road segment images and stores them on the open-source platform Mapillary. The subsequent analysis “can automatically identify 106 street characteristics [...] such as road signs, streetlights, street markings, bike lanes, sidewalks, and potholes” (GRSF 2022).

Indicative of the general framing of the GPRH’s approach, it is emphasized that these methods reduce the “reliance on traditional methods of manual image annotations” and that “the workflow

is replicable in other locations”(GRSF 2022). Not unlike the humanitarian framing of its predictive mapping, a blog post states that “Road safety analysis is crucial to protect people’s lives by preventing road fatalities and injuries”, arguing that “the availability of high-quality and reliable data so that we can extract useful, actionable insights and enhance road safety conditions“(Antos and Triveno 2023). This engagement takes up central elements of the GPRH’s approach and applies them to the new area of road safety: the claims to efficiency and replicability of its methods, the humanitarian impetus to save lives, and the apparent ‘lack of data’ as the underlying problem to be addressed through geospatial intervention.

As a novelty of this application in the transport sector, two machine learning models for the evaluation of road safety were created. One model was trained on street view images to extract “information about road characteristics such as crosswalks, sidewalks, streetlights, traffic signs, and utility poles”(Antos and Triveno 2023). The second model aimed “to evaluate road risks in selected areas”, producing road risk predictions that could be compared with available traffic data (Antos and Triveno 2023). Another new element of this collaboration is the use of ‘big data’ sourced by private companies. For example, the project used ‘crash alerts’ from the ride-sharing platform WAZE and road characteristics extracted from street view imagery uploaded to Mapillary. The report thus suggests that “it is vital for road safety practitioners and governments to work with companies through data partnership agreements to unlock their immense potential” (Antos and Triveno 2023)

Just like the GPRH’s technical guidance notes on drone mapping, the collaboration did not only aim to improve road safety locally but also aimed to share the methods for replication. A guidance note intended for task team leaders explains “how this data could be incorporated into the World Bank project cycle and more specifically into the tools or models they already have” (Antos and Triveno 2023). The report details the program’s use of ‘big data’ and machine learning for road safety analysis (GRSF 2021). The first part “provides an overview of existing approaches and tools for road safety assessment and identifies opportunities to improve these using new technologies such as big data and ML” while the second provides “concrete guidance on how they can be integrated into transport projects for road safety analysis”(GRSF 2021, 5). The third part then presents case studies on two ‘regions of interest’, which consist of two cities where the program was already active, Bogotá and Padang (GRSF 2021, 5). Citing the strength of Bogotá as a ‘model city’ for urban risk management (Zeiderman 2016, 194), the team shared the data with the municipal government “for further validation and inclusion into a neighbourhood vulnerability index they are creating”(Antos and Triveno 2023).

The comparison between Bogotá and Padang had the three stated objectives to: “1. Learn how well big data and ML can be used to identify road features, estimate road safety, categorize road segments based on their risk level, and identify high-risk segments; 2. Evaluate the utility of several big data sources that are freely available for road safety analysis in diverse geographic areas; and 3. Assess the replicability of the proposed approach“(GRSF 2021, 35). Just as in other pilot projects, the report emphasizes the advantages of this comparative mode of knowledge production, stating that “the selected locations offer an opportunity to apply the framework on paved, urban roads in contrasting environments, particularly related to data availability and usability”(GRSF 2021, 35).

FIGURE 18: Road risk prediction in Padang



SOURCE: Original figure for this publication, based on data from OSM and data provided by the Waze App. Learn more at waze.com. Drone imagery provided by the World Bank Global Program for Resilient Housing.

Figure 14: Road risk prediction in Padang. The risk level of specific roads was calculated using Street View imagery analysed by machine learning combined with traffic data from the private WAZE platform (GRSF 2021, 46).

Similar to how the GPRH’s engagements in the housing sector recommend governments to expand their geospatial capacities, the report also suggests that “governments, road safety advocates, and international development organizations will want to consider investing in platforms and tools that specialize in collecting and analysing data for road safety (GRSF 2021, 49). This combination of experimental pilot projects to test its methodology, flanked with recommendations to integrate such modes of seeing into existing government institutions, is typical for the GPRH’s global operations.

The collaboration with the GRSF once again demonstrates the GPRH's flexible mode of operation across multiple sites and with different partners. This specific collaboration was financially supported by UKAID and incorporated inputs and reviews from the GRSF’s transport specialists,

as well as external industry experts (GRSF 2021, 4). An interviewee familiar with this road safety project explained that the partnership occurred because they had access to “pockets of money” from the Bank’s transport branch, and from the realisation that “once we had these algorithms going, this technology could also be useful for road safety or traffic” (Interview, 23.04.25, S. 6). Again, the position at the World Bank allows the GPRH to form global partnerships with various programs and leveraging third-party development funding, leading to unique constellations for situated geospatial experiments.

Assessing Housing from the Sky and Street

“In 2024, using machine learning and imagery collected from the sky and street, we can finally make Jacobs’ vision from 1981 a reality: widespread, simple visual analysis that helps inform urban development and, ultimately, improves people’s lives”

GPRH, ‘Jacob’s Dream’²²

At its very core, the GPRH’s geospatial methodology facilitates the digital legibility of informal settlements for subsequent targeted interventions. The stated promise of these methods is that “[p]roperty valuation, vulnerability and housing needs assessments can be produced in an automated way in a fraction of the time and at a fraction of the cost” (Triveno and Antos 2019, 55). These assessments are based on visually capturing physical urban space and using machine vision to interpret the collected urban imagery.

This chapter will examine how the GPRH’s methodology and workflow translate the urban materiality of informal settlements into housing data and legible cadastral maps.²³ In line with STS studies on urban resilience, it describes the “*process of mapping*” and analyses the “*format in which information was presented and mapped*” (Borie, Ziervogel, et al. 2019, 4). The central epistemic objects of this workflow are the housing units, which undergo a complex process of digital abstraction and finally assume the form of ‘housing passports’ with fixed boundaries and distinct characteristics. The chapter concludes by describing how the collected information is

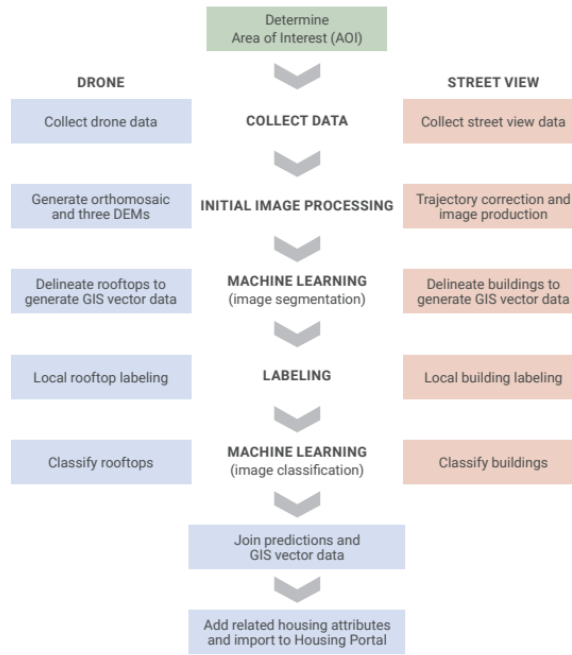
²² Quote from the blog post titled ‘Jacob’s Dream: Improving Disaster Risk Management Using Visual Clues in the Age of AI and Machine Learning’ (GPRH, 2024).

²³ As illustrated in the previous chapter, the GPRH’s methodology was often adapted between its mapping sites, depending on practical challenges or different applications. The procedures described here should therefore not be seen as a static or definitive workflow, but rather as an approximation of the relatively mature state of the methodology, as documented in technical guidance notes and explained in the interviews.

visualized for users as thematic cadastral maps through a customized 'Housing Portal'. This shows that these technical procedures constitute operational chains that act on the epistemic objects at hand, gradually alienating the houses into digital objects separate from their social contexts.

The examination of the GPRH's seemingly automated capturing of urban space illustrates the many sociotechnical prerequisites and distributed decision-making power of these data workflows and algorithms. It therefore aims to "open up the black box of data-driven analytics" (Safransky 2020, 205) and to demonstrate how these algorithms operate through "an assemblage of people, institutions, and technologies" (Safransky 2020, 202). This section also demonstrates that "the logics of automation and predictability within AI futures require an enormous array of digital labour that is often precarious and casualised" (Datta and Muthama 2025, 286). Due to its global operations and diverse applications, the GPRH forms a global network of geospatial knowledge production, thus posing an interesting case for these conceptual literatures. It links the different mapping sites where the World Bank collected data, private geospatial companies such as Development Seed, outsourced data teams that worked on data labelling in Peru, and even volunteers who competed in a 'hackathon' to develop some of the program's rooftop classification algorithms.

FIGURE 2: GPRH workflow



SOURCE: Original figure for this publication.

Figure 15: Schemata of the GPRH workflow (GPRH 2022c, fig. 2)

‘Capturing Housing Data’

The first critical moment of the GPRH’s housing assessments occurs when urban materiality is first registered by cameras and sensors. These included cameras and 3D sensors mounted on eBee X drones, as well as 360° Street View Trimble MX7 system mounted on a car, motorcycle, or backpack. The program also used satellite data to model terrain and building heights (GPRH, 2019, p. 43). Capturing the urban landscape and producing the multi-view imagery for visual analysis requires expensive equipment and urban sensing instruments.

The mapping process also required manual labour in the ‘field’. An interviewee involved in Street View collection stated that “it was a very tedious work to go into the field and then collect the Street View imagery. It was not easy to navigate, especially in informal settlements where streets are very narrow. In some instances, you cannot ride your car, so you have to walk with a stick and use a handheld camera” (Interview, 10.03.25, S. 10). In Padang, some of the data collection was subcontracted to local consultants once the methods were “firm” to some degree (Interview, 10.03.25, S. 11). This was deemed “more efficient because local firms can navigate the local areas easily” enabling them to “cover a much wider ground than by collecting ourselves” (Interview, 10.03.25, S. 10). While this introduced a participatory element into data collection, it

should not be understood as community mapping, but as outsourcing, as the methodology and workflow essentially remained the same.

Data collection by drone and Street View was done in bursts of a few days of recording, with periods of travelling on weekends. This ‘fieldwork’ is the only step in the workflow during which program members could encounter inhabitants of the targeted settlements. Some of these social encounters were also narrated by interviewees, who described the interactions with locals as friendly and fun, and that kids were “having a blast” and were curious about the drone equipment (Interview, 05.04.25, S. 22). However, he also described the settlements as a “very urban space” that had an impression on him, pointing out that “the level of infrastructure... it certainly affects you. You would have to be a robot for it not to...” (Interview, 05.04.25, S. 25 - 26). Indicative of the program’s ‘socially distant’ approach, the engagement with local communities during the mapping process was limited to brief social interactions. This essentially reduces these settlements to geophysical landscapes to be precisely digitalised, rather than as socially meaningful spaces to be explored through other means.

The GPRH’s multi-sited operations also posed logistical and organizational challenges regarding data collection. One part was the need for high-tech equipment, such as eBee X drones or a Trimble MX7 Street View system, along with related cameras and sensors. In some cases, GPS base stations had to be installed to ensure accurate geolocation of the images taken (Interview, 05.04.25, S. 6). An interviewee mentioned that the frequent travels for the GPRH’s many dispersed mapping missions could be a challenge as they sometimes required him to take the drone battery (“a big brick”) with him on the airplane (Interview, 05.04.25, S. 24 - 25). Furthermore, before flying the drones and capturing images in new places, flight path planning was required (GPRH 2022c, 24), for which suitable and accessible open areas, such as football fields, for take-off and landing had to be scouted (Interview, 05.04.25, S. 15). The synthesis report on the GPRH’s mapping in Mexico mentions some of the practical challenges the World Bank faced in data collection, namely “strong wind (up to 12 mph daily), steep terrain, and minimal access to take-off and landing sites”(GPRH 2019a, 43). It is also mentioned that “[p]rotests and deteriorating security conditions resulted in less than anticipated Street View data collected in Juchitán” (GPRH 2019a, 43). Such unforeseen incidents show that access to these sites cannot be taken for granted but could be complicated for various reasons. This demonstrates the logistical challenges of the program’s mobility, which required extensive resources and authority not readily available to other actors. In the words of one interviewee, “that was totally the benefit of doing these projects through the World Bank, everything was pretty streamlined” (Interview, 05.04.25, S. 23).

Another challenge was the bureaucratic process for obtaining licenses for data collection, which differed significantly from site to site. For example, obtaining permits for aerial data collection in Indonesia required at least seven types of security clearances and recommendation letters (Triveno Chan Jan, Antos, and Rufianne n.d.). The program thus faced questions about the protocol for obtaining the necessary clearances for collecting this type of imagery. However, as these methods were so new, there was often no real regulation. As one interviewee put it, “it is so new... and who could stop you from taking a photo in the street?” (Interview, 23.04.25, S. 20). Many such challenges and practical procedures for data acquisition were documented in a guidance note on ‘Capturing Housing Data’ (GPRH 2022c). This shows that the knowledge produced through these missions went beyond mere technicalities but also concerned the experiences gained by technicians through ‘fieldwork’. By sharing their learnings and planning documentation with a broader development community, the GPRH also offers guidelines that support the potential replication of such urban mapping by other actors.

The practical procedures and challenges of data collection by drone and Street View described here, showcase the technical requirements, manual labour, and logistics needed to capture such diverse and geographically dispersed urban environments. The practical labour of conducting drone surveys and collecting Street View imagery constitutes the very first steps in the process of digitised enclosure (cf. Cowan 2025b, 2). It was the broader institutional power and support of the World Bank that enabled the GPRH to conduct its mapping operations. The short-paced extraction of housing data represents the only step in the GPRH’s workflow where potential feedback from inhabitants could be received, as the program otherwise never deliberates with locals and most subsequent processing is done elsewhere.²⁴

Data Preparation and Labelling

To assign each image to a unique location on planet Earth, the drones and cameras first had to be integrated with the geodetic grid. This was an important precondition for further analysis, as the drone and Street View images must share the same geodetic basis to be combined and attributed to houses (GPRH 2022c, 14). An engineer explained that the available satellite imagery of the targeted settlements was often too low-resolution to be used for georeferencing (Interview, 05.04.25, S. 18). Hence, it was sometimes necessary to intervene in the spaces at hand to improve

²⁴ This is stated in a post that was made during COVID-19, which states that “The methodology of the Global Program for Resilient Housing (GPRH) relies entirely on remote technology perfectly suited to current COVID-19 requirements. Images of the houses are captured from drones and car mounted cameras and then processed entirely in a home office” (Triveno, Terraza, and Antos n.d.)

accurate geolocation. One method used by the program was to establish GPS base stations in the areas of interest to calibrate the drones and sensors with adequate accuracy (GPRH 2022c, 15). Another method for georeferencing entailed “the placement of high-contrast aerial targets throughout the survey area to serve as ground control points”(GPRH 2022c, 17). The underlying technical procedures show that the visual enclosure of urban settlements requires significant preparatory work, technical platforms, and geospatial expertise, which is often rendered invisible by framing this process as ‘automated’.

After data collection, the ‘raw’ urban images had to be prepared for further analysis. The drone and Street View images were first processed and analysed separately, then combined by attributing them to a single ‘building footprint’ [Figure 16]. The main output for the drone imagery was a composite image of the ‘area of interest’ stitched together from the different aerial images. The 360° Street View images, on the other hand, were cut into six cubicles (top, bottom, front, back, right, left) using software to extract images for labelling. A technician responsible for this task mentioned that preparing this took considerable effort, as the collected imagery covered many kilometres of streets in each city. The output was a “folder of images with tidy naming that are linked to locations” which were then passed to Development Seed for further processing and machine learning (Interview, 10.03.25, S. 4).

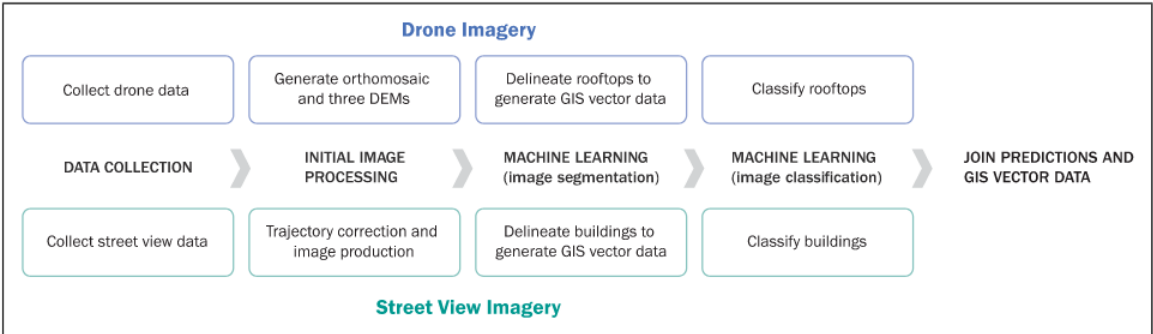


Figure 16: Workflow from data collection to the joining of prediction and creation of a GIS dataset.

Arguably, the most laborious step in the workflow is labelling. This required a team of data specialists to manually identify relevant features on the collected images to create a training dataset for machine learning. A labelling guide published by Development Seed outlines this “process of finding and labelling features that are relevant when assessing a building’s resiliency” (DevelopmentSeed 2023). In practice, this meant going through hundreds of thousands of images and drawing boxes around features that seemed relevant to analysis (e.g., windows, doors, signs).

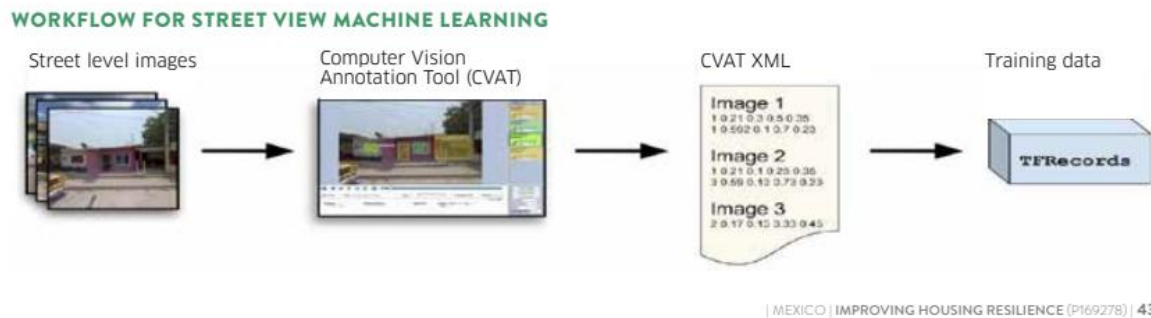


Figure 17: Simplified schematic of the GPRH’s workflow for Street View Machine Learning. The CVAT software is used for manually labelling the individual images (e.g. identifying windows, doors, building materials) to create training data (GPRH 2019a, 43).

The initial feature extraction from the images was done manually using a customized computer vision annotation tool (CVAT), which enabled splitting images across the data team and allowed quick-paced labelling of one image at a time. For each physical characteristic, sufficient manual input was required before models could draw statistical inferences. A technician described repetitive labelling work as follows, “this image is bricks’ ‘it is bricks’ ‘bricks’ ‘bricks’ ‘bricks’ for 1,000 or 500 times or so” (Interview, 10.03.25, S. 11). This digital work was largely handled by Peru-based data team specialized in creating training datasets, which later formed its own geospatial company, GeoCompas. One of its members stated that, in the end, they must have created over 20’000 manual labels for the machine learning datasets (Interview, 13.03.2025).

The final categories used to classify the houses were not fixed from the beginning but only emerged from this ongoing digital work. It was during the labelling process that some visual characteristics proved meaningful, that categories were defined, and edge-cases were resolved.²⁵ As one technical put it, “the problems you’re trying to tackle always look very simple, but the moment you start labelling, so many edge cases and doubts [appear], and very specific domain knowledge is needed” (Interview, 25.02.25, S. 6). The labour of the digital workers who manually labelled image after image essentially filtered out the relevant building characteristics that could later be used for automated assessments. The final set of classes, shown in Figure 18, included structural characteristics of the building (building materials, construction, condition), such as the number of doors or windows, the percentage of openings, and building materials, as

²⁵ One of such edge-cases was described as follows: “one [edge-case] was very funny. They were drawing boxes around doors, and then they were on the Street View, looking, ‘where are the doors?’ Suddenly, they get to fields on the outskirts of the city. Except in one of the fields, there was a door just standing in the middle of the field. I do not know. Somebody was storing it there or something. Then the question is, okay, do we label that? Because it is a door, but it is not a door in the context of buildings... Anyway, so you get all these very little edge cases. Then, what the data team would do is they would build these enormous wikis, documenting these edge cases” (Interview, 25.02.25, S. 6 - 7).

well as building use (residential, commercial, critical infrastructure). The same workflow was used to label rooftops from an aerial perspective, though here other classes, such as roof material and roof condition, were most relevant.

Table 1. Urban characteristics captured by drone and street view imagery, inspired by urban clues in *Looking at Cities* (AB Jacobs, 1985). Apart from building size, most building characteristics are derived through machine learning.

Clue	Characteristic	Description	Drone	Street View
Purpose	Use	Residential, commercial, mixed		x
	Size			
	Area	Estimated roof area in square meters	x	
	Height	Average (mean) height of the building in meters	x	
	Volume	Estimated volume of the building in cubic meters	x	
Material	Roof material	Concrete, metal, mixed, tile, other	x	
	Wall material	brick or concrete block; plaster; wood—polished; wood—crude/plank; adobe; corrugated metal; stone with mud/ashlar with lime or cement; container/trailer; plant material; mix/unclear/ other		x
Construction	Masonry	Unreinforced masonry, reinforced masonry, unknown		x
Condition and maintenance	Roof condition	Good, fair, poor, under construction or vacant	x	
	Wall condition	Good, fair, poor		x
	Total condition	Composite estimation using roof and wall condition	x	x

Figure 18: An overview of the most important urban characteristics captured by the GPRH. As indicated by the last two columns, one of the most important innovations of the GPRH’s mode of urban analytics was the combined use of drones and Street View (Gosling-Goldsmith et al. 2024, tbl. 1).

Even if rarely acknowledged in the GPRH’s promotional media, the manual labour of identifying relevant elements, sorting out edge cases, and creating categories was a fundamental prerequisite for the automation of the mapping process. A data specialist explained that “if you do not have really good training data, then you are not going to get the attributes that you want... Otherwise, it's garbage in, garbage out” (Interview, 05.04.25, S. 8). This array of intuitive judgments by data engineers is gradually compiled into machine learning models, which can then be used to automate extraction processes on a large scale. As this training process is later ‘black boxed’, it is next to impossible to retrospectively trace the way such algorithmic decisions (e.g., whether a specific building is deemed plaster or brick, low or high risk) are ultimately made.

Model Training

The very core of the GPRH's methodological development was its machine learning models. External partners of the World Bank, primarily the geospatial company Development Seed, conducted most of the machine learning research and development. For the most elaborate algorithms, the program also collaborated with machine learning specialists from US universities

(Wang et al. 2023). It even hosted an AI data challenge based on its training data in 2019, which attracted 1’419 volunteer participants who contributed free digital labour from across the world.

Based on datasets created through manual labelling, Development Seed trained multiple machine learning models to recognize the relevant building properties from images automatically. As stated in a blog post, “Speed and cost are the key here; once trained, this ML system is capable of processing over 300,000 images in one hour for about 1.5 USD”(Wronkiewicz 2019). Models were trained for different purposes; the most important were feature extraction from images, as illustrated in Figure 19, and subsequent classification of buildings based on different physical characteristics.

FIGURE 8: ML algorithms and street view

After applying an object detection algorithm to a street view image, a bounding box surrounds each predicted object, which also contains a confidence level for each prediction.



SOURCE: World Bank Global Program for Resilient Housing.

Figure 19: Illustration of the feature extraction process through machine learning. This involved drawing ‘bounding boxes’ as well as calculating the uncertainties involved (GRSF 2021, 29).

The bulk of the methodology development was done in the early engagements of the program based on data from only a few cities. After the first models had been trained, the process involved iterative model training and evaluation using data from new sites or applications (Development Seed 2024). This ongoing which was tightly coupled with the mobile operations of the GPRH, as models were constantly re-adapted by “replicating this in another city, creating more training level data, and slightly adapting [the model] to a different context”(Interview, 25.02.25, S. 11). An interviewee explained that the machine learning models were first trained at the scale of cities or countries, but that datasets from different sites were later combined to build regional models and even global models that performed relatively well across different sites (Interview, 13.03.2025, S. 5).

After the basic workflows were established, new models could be trained or existing data reused for other applications. The collection of urban imagery and the labelling of training data were ongoing procedures that determined the outcomes of model training. The GPRH's work was therefore much less about producing static outputs or definite models, but much more about establishing the sociotechnical infrastructures, including its workflows, algorithms, and platforms and its global divisions of labour.

Not all model training was done by DevelopmentSeed. In one instance, model training was 'crowd-sourced' by hosting an "Open AI Caribbean Challenge" on the platform DrivenData, as part of a series of 'Open AI' challenges. This competition invited tech-savvy volunteers from all over the world to "Join the ML Housing Revolution by helping us extract more knowledge from imagery" (DrivenData 2019). The GPRH provided a dataset of aerial imagery of seven different areas of interest in Colombia, Guatemala, and St. Lucia. The goal was for participants to develop machine learning algorithms to classify different types of rooftops based on the training data shared by the GPRH. The key challenge was: "Can you predict the roof material of buildings from drone imagery?"(DrivenData 2019).

At its completion in December 2019, 1'419 participants had joined the GPRH's challenge by submitting their own rooftop classification algorithms. The winners were determined by how closely the participants' algorithms identified rooftop materials compared to a separate validation dataset. The winning team of the 10'000\$ prize money consisted of two machine learning experts from Russia and England. Paradoxically questioning the validity of their own work, the winning team noted in their report that "the biggest issue of this competition is data quality" and that "there are lots of roof labels in training data which are clearly incorrect"(DrivenData 2019). They lamented that many of the data samples provided by the GPRH were clearly mislabelled, citing an instance where a piece of road was mislabelled as a heavy-metal roof. This indicates the questionable status of the 'ground truth' constituted by such digital datasets. Participants could have developed algorithms better able to identify the material reality, but doing so would have barred them from winning the challenge, since they were being ranked based on the mislabelled datasets provided by the GPRH. This shows that these datasets are abstracted from the urban landscapes initially captured. They constitute a new digital reality which has real-world implications, not just for the ranking of online challenges but, more importantly, also for the systems of urban governance built on them.

The DrivenData competition had been arranged through one of the GPRH's temporary consultants and remained unique (Interview, 23.04.25, S. 27). The premise of this challenge is quite striking: high-resolution drone imagery from three seemingly unrelated settlements was shared with a

bunch of strangers online to develop rooftop classification algorithms about housing in places they likely never were. If the program ever applied the winning algorithms, the technical decisions of their creators could directly affect the allocation of retrofitting resources or housing subsidies in these areas and beyond, potentially without the inhabitants ever becoming aware that their houses were being assessed. The collective, unpaid work put into the 1'419 submissions to the competition not only illustrates the dispersed and networked nature of the GPRH's geospatial knowledge production, but also its partial reliance on an “enormous array of digital labour that is often precarious and casualised” (Datta and Muthama 2025, 286).

‘Building Footprints’

Using the overhead drone imagery as a basis, machine learning models are used to generate a rough outline of the buildings in the mapped areas. This seemingly mundane step of the workflow is needed to attribute the images to individual houses. This step of the workflow marks the moment when the boundaries of individual buildings are digitally fixed for the first time. As elsewhere, such geospatial technologies are employed “to consolidate a new perceptive register in which property is understood as severable, bounded and individually owned” (Cowan 2025a, 198). These building footprints constituted the basis for creating digital cadastral maps, in which the predictions of the building characteristics could be stored.



Figure 4. The urban rooftop vector layer, shown in yellow, overlaid on the orthophoto mosaic (left). Clustered rooftops were reviewed and manually divided, if necessary, as shown in red, on top of the digital object model (right) to create a building footprint layer.

Figure 20: The urban rooftop vector layer from which ‘building footprints’ were derived to form a first version of a cadastral map, to which the predicted building characteristics could be attributed (Gosling-Goldsmith et al. 2024, fig. 4)

The high-resolution imagery captured by drones enabled the creation of map by drawing digital boundaries between houses, thereby enhancing the legibility of the settlements from an aerial perspective. A leader of the program explained that they had attempted to use satellite imagery for this, which would have been readily available; however, they had “mixed results” with this data

source due to its lower resolution. She emphasized the challenges of the building typology of informal areas: “some of the neighbourhoods where we worked had very small housing... It was hard to tell where one roof ends and the next begins, even with drones”(Interview, 23.04.25, S. 12). A drone specialist reiterated such challenges the built form posed for digital legibility: “if you have a tolerance of 3 to 10 meters and you are mapping in these areas where it is really impoverished communities and they are right stacked next to each other, different heights, but different roof conditions... It gets really difficult to have a degree of confidence in your results” (Interview, 05.04.25, S. 18).

One of the technicians explained that these quick first maps of the “building footprints” were “not very accurate, especially when there is a row of houses. It is very difficult to automatically identify the boundaries of row houses. Those are part of the tedious cleaning process that I had to do as well... to redraw some of the outlines of the buildings, clean up the data before handing it over“(Interview, 10.03.25, S. 12). As the quote indicates, drawing spatial boundaries to demarcate individual housing units appears as a surprisingly mundane task. Nevertheless, the demarcation of individual plots is a thoroughly political act. In the context of large-scale land digitalisation schemes in India, for example, land surveyors often faced contestation or had to negotiate with locals over how exactly property boundaries are drawn (Cowan 2021). In this case, however, geospatial engineers intuitively decide for themselves where one housing unit ends and another begins, without deliberation with inhabitants.

It is in this step of the workflow — the digital generation and redrawing of outlines from aerial imagery — that urban settlements are subdivided into separate, bounded housing units. This process of digital enclosure occurs irrespective of any divisions or property regimes already in place, effectively treating the settlements as a *Terra Nullius*. The stated primary purpose of this housing data is to identify vulnerable structures for planning and further inspection, for which the exact distinctions between houses may indeed not be that relevant. In contexts where the same maps are later used to create a formal cadastre, to value properties, or for tax collection, the placement of these lines can make a significant difference. This delineation of individual houses creates a preliminary cadastral map that sets impactful precedents for future uses of this housing data.²⁶ The map of ‘building footprints’ constitutes the digital output of the consolidation of the

²⁶ As highlighted in an interview with one of the GPRH’s leaders, the potential use of their methods for the creation of official cadastres was considered, however, never pursued on a large scale: “Some countries don’t have a cadastre. You could actually use this information to build a cadastre because of the precision... The difference is, I think we are talking about some centimetres of difference between the accuracy that we can provide, and a real cadastre can provide. The cadastre is a starting point of the regularization because you identify what’s there”(Transcript_Triveno_04-06-25, S. 11 - 12).

informal settlements “into standardised, partible plots that can easily be identified through platform data visualisations” (Cowan 2025a, 198).

The building footprints are essential for the subsequent data processing chain, as they are required to attribute building characteristics to specific structures. The Street View cameras capture images roughly every 2 meters, meaning that every building was captured at least 5-10 times from different angles. This resulted in multiple images and, hence, multiple machine learning predictions of the physical characteristics of each building. These had to be attributed to a single building footprint by using the car’s location and camera angle at the exact moment each image was snapped. The average of predictions from different angles was then taken as a definitive assessment of the building and its characteristics.

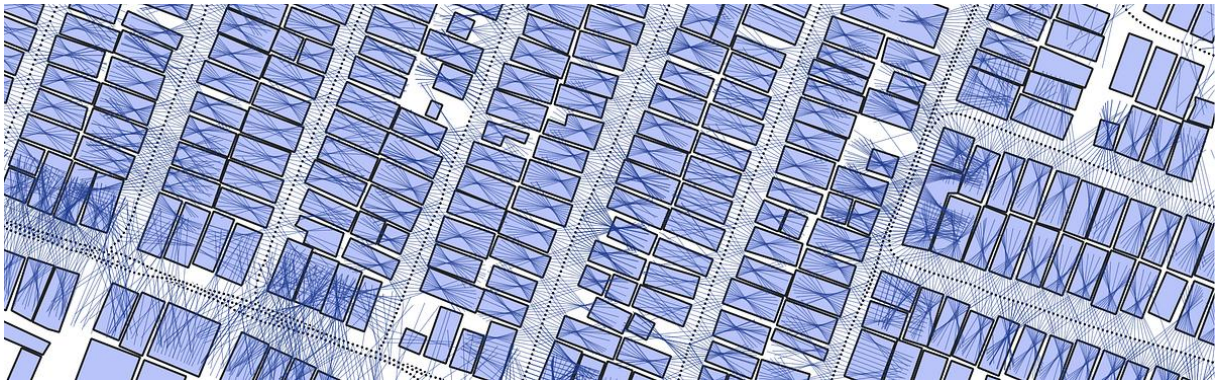


Figure 21: Schemata explaining the attribution of singular images (points) to building footprints by using the angle the camera was facing at the moment of image acquisition.

The triangulation methods for attributing multiple Street View predictions to individual housing units constitute some of the GPRH's most important methodological innovations. In a blog post, this procedure is described as follows: “we distil these ML detections into one determination per building attribute, similar to an engineer making a single determination after inspecting a building from different angles” (Wronkiewicz 2019). Of course, such predictions are only useful in practice when they can be related back to a specific building. These geometrical calculations constituted “the final link between the Street View images and our top-down map” and allowed the assignment of the predicted physical characteristics to individual, locatable housing units (Wronkiewicz 2019).

‘Housing Passports’

The predicted characteristics (e.g. built with brick, 79% certainty) were ultimately stored and visualized as ‘housing passports’, a format that creates a unique and legible profile for each home. This interactive tool consists of a map, where clicking on a ‘building footprint’ would display the information available for each house (Interview, 25.02.25, S. 13). This includes the building

properties derived from machine learning, as well as other available information, such as its exact location, Street View images, risks factors, building values, or available census data (Wronkiewicz 2019). These ‘passports’ served to compile all housing data processed through the GPRH’s workflow in a legible, accessible way, with the aim of “facilitating comprehensive analysis and decision-making” (Development Seed 2024).

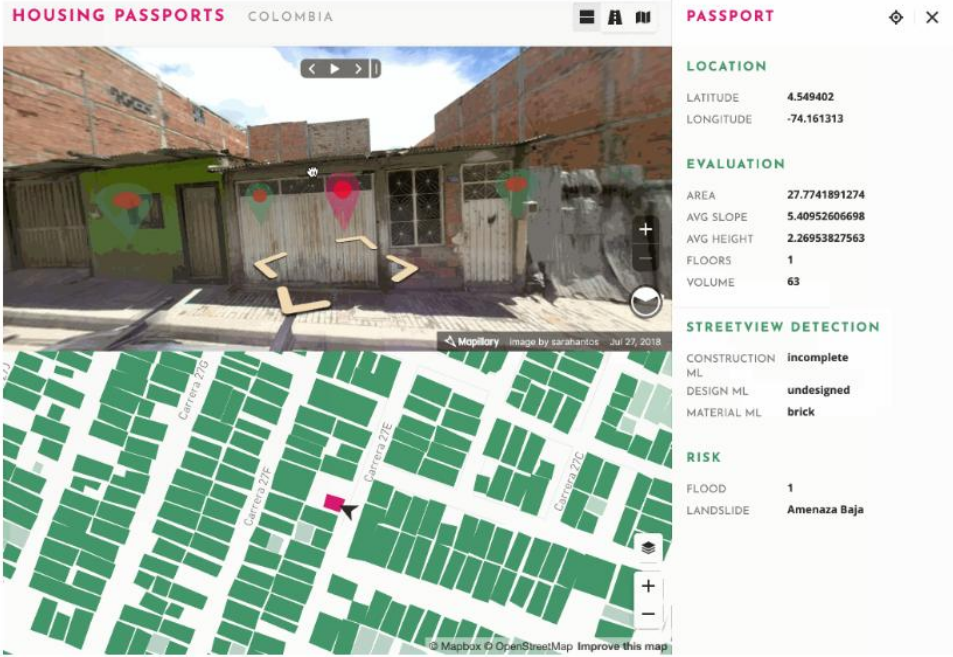


Figure 22: Screenshots of the ‘Housing Passport’ platform, where users can virtually navigate the mapped settlements and view Street View images and attributed characteristics (Wronkiewicz 2019)

Although the ‘housing passports’ are not currently linked to their inhabitants, their format and functionality illustrate how “property technologies operate via existing biometric identification and citizenship technologies” (Ghertner 2025, 297). As other passports, this format provides each unit with a unique digital identity whose characteristics are used to differentiate their handling in governance. The platform also offers the potential to be used for property regularization. As explained by one of the GPRH’s leading members, the program piloted a function that would allow families to upload information, such as water bills, rental contracts, or sales agreements. This digital documentation could then serve as the basis for regularization and inform families about how close they are to their title (Interview, 04.06.25, S. 12). By applying identification formats to housing units, they extend the “the bureaucratic fixation on the accuracy and integrity of information” of the digitalising state into informal settlements, (Shoshana Goldstein 2025, 218).

‘Housing Portal’

A second platform for aggregating and visualizing housing data at the neighbourhood level is the GPRH’s ‘Housing Portal’.²⁷ This digital platform compiles data from different sources and is introduced as a “portal to find, build and strengthen homes” which allows users “to visualize and analyze the housing stock” (Triveno Chan Jan, Antos, and Rufianne n.d.). The housing portal showcases the diversity of housing data produced by the GPRH and hints at their potential uses for governance. The digital platform thus embodies a distinct vision of data-driven governance of housing.

The housing portal constitutes the endpoint of the sociotechnical assemblage and collective workflow behind the GPRH’s technology component. It is stated that the data aggregated in the portal contains “actionable knowledge to design and implement housing plans as well as to activate construction, credit, and insurance markets” (GPRH 2022b). The platform is designed to be interactive and, depending on the available data, can show more than 25 different housing characteristics. As shown on Figure 23, these can be filtered for different use purposes and allow “users to define their own areas of analysis and examine their neighborhood or block” (Triveno Chan Jan, Antos, and Rufianne n.d.). Presented to the user as a variety of interactive and thematic maps, the housing data is presented in the characteristic form of data-driven urban governance of the ‘Urban Dashboard’ (Datta and Söderström 2024; Kitchin, Lauriault, and McArdle 2015). There are, however, clear limitations to what is (not) included on these digital platforms. Unlike manual housing surveys, the ‘socially distant’ mapping process of the GPRH does not allow the integration of any qualitative information about these houses or their inhabitants; the platform is therefore strictly limited to physical characteristics and classifications derived from machine learning models.

²⁷ The prototype of the housing portal can be accessed online: <https://gprhportal.org/>



Figure 23: Screenshot from the Housing Portal, showcasing the selection of an 'area of interest' in Padang, Indonesia and related statistics (Triveno Chan Jan, Antos, and Rufianne n.d., 12).

The 'Housing Portal' effectively demonstrates how the GPRH's methodology facilitates the legibility of the targeted urban spaces. The building outlines derived from drone images now form a preliminary cadastral map to store and visualize housing data, most of which are based on predictions from the program's machine learning models. While the models and calculations differ across the maps shown in the screenshot in Figure 24, the underlying "mapping process" and "the format in which information is presented" are essentially the same (Borie, Ziervogel, et al. 2019, 7). The mapped settlements are now presented as interactive digital maps that enable users to use this data for targeted interventions. How exactly local governments or other actors make use of this digital legibility varies from case to case and could not be explored in detail. Nevertheless, the portal shows that the purposes of this housing data are not at all limited to matters of urban resilience, but can include thoroughly political matters such as taxation, property valuation, and even migration.

FIGURE 1. GPRH Housing Portal

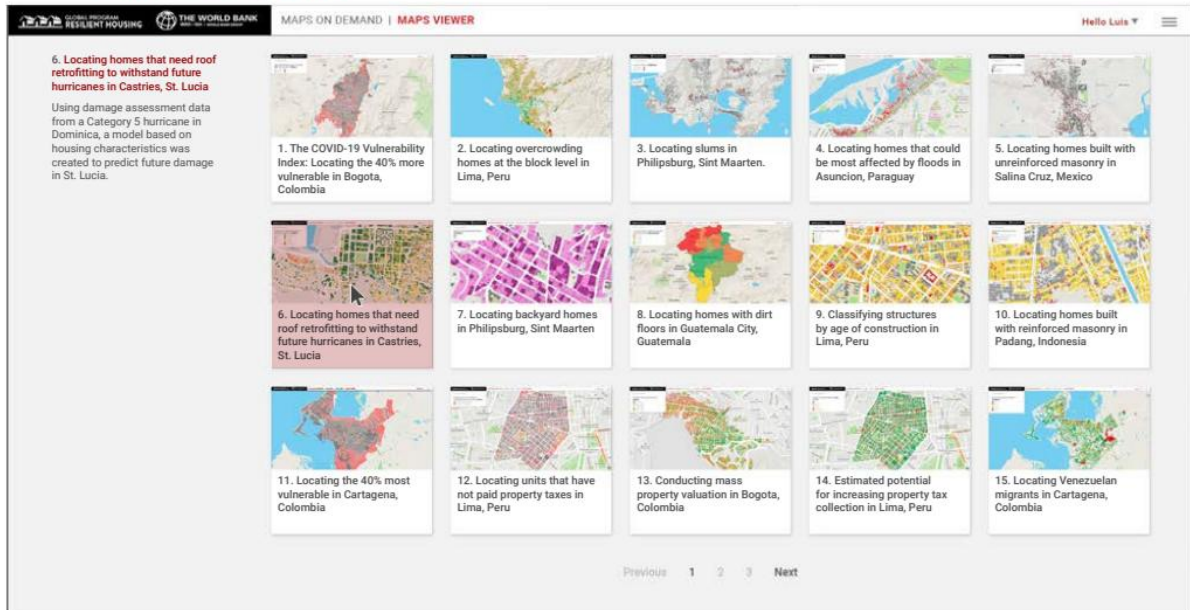


Figure 24: Screenshot of the GPRH Housing Portal with housing maps for different use purposes (GPRH 2022c, 11).

The GPRH turns informal housing into a digital object, thereby extending urban governance into peripheral spaces previously not addressable in the same way. Similar to other geospatial systems used for urban risk management, the housing portal visualizes spatial data to target high-risk neighbourhoods, populations, and houses, effectively enabling a new “field of governmental intervention” (Zeiderman 2016, 73f). The GPRH’s workflow and technical procedures aim to render previously illegible urban peripheries into preliminary cadastre maps with bounded, individual properties, therefore incorporating them into the informational logics of the core. The platforms on which this housing data is finally visualized and presented show that this process leads to a platformisation of informal housing. The fact that the same platforms can potentially be used for property regulations corresponds to the observation of Thomas Cowan, who observes that property digitalisation programmes “are conduits toward a configuration of new, and perhaps rather unpredictable, form of digital citizenship”(Cowan 2025a, 192).

Uncertainties and Limitations

Many technicians interviewed readily acknowledged the uncertainties and limitations inherent in the geospatial methods used. A common observation was difficulties in communicating these uncertainties to decision-makers and stakeholders less familiar with the underlying technical procedures. Despite the program's promise of providing efficient and objective housing assessments, these digital methods lead to entirely new forms of limitations than the housing surveys they claim to overcome. While limited in scope by the level of analysis, this section

engages with some of “the messy sociomaterial uncertainties” written into the GPRH’s approach to “territorial calculation” (Cowan 2021, 456).

According to a program member involved in negotiations with local governments, the team “had to be careful of managing expectations because they saw us come in with all this fancy equipment. And really, all we were doing was imaging... We were not coming in with money to build new things. So, we tried to keep it clear that this was just a Rapid Assessment” (Interview, 23.04.25, S. 19).

The program members sometimes faced scepticism about the accuracy of its predictions and risk maps. Some partners questioned the reliability of the house risk classifications, prompting the team to add a feature to the housing portal that showed the level of confidence for each prediction (Interview, 23.04.25, S. 17). A senior geospatial expert attributed this to the different standpoints of researchers and government officials: “as researchers you are like: ‘man, not bad, 90% accurate’. But they say: ‘Hey, one out of 10 buildings is wrong. What kind of model is this?’” (Interview, 27.03.25, S. 23). Such disjunctions were even stronger when the models produced building shapes or predictions that were clearly implausible to the human viewer. A related problematic was that the machine learning predictions were quite sensitive information. As a geospatial specialist put it: “suddenly we were saying: ‘Hey, this person's home is moderate to high likelihood of damage during an earthquake or a typhoon’, which could have consequences on that person's value of the property” (Interview, 23.04.25, S. 17). This was part of the reason the program limited access to the ‘Housing Portal’ to selected partners.²⁸

From an engineering standpoint, the program’s visual assessments are too uncertain to support definitive decisions, as they are limited to the appearance of the outer housing envelope. While high-resolution, the imagery still occludes crucial factors for the stability of housing units, such as the connections between walls and the rooftop, which are only visible from inside the house. An experienced Build Change engineer explained that although the remote assessments provided by the GPRH were really helpful for broad planning and political negotiations, on-site assessments by a trained engineer would still be necessary for any definitive assessments (Interview, 26.03.25). Somewhat tempering the program’s bold vision, a core member of the GPRH also talked about the “pushback” received from engineers, who emphasized that “you need to go to each one of these buildings before you can make any type of decision, because there are a lot of things that you cannot see with the imagery” (Interview, 23.04.25, S. 16).

²⁸ This also impacted my data collection, as I could not directly access any of the spatial data or maps produced by the GPRH, except for the freely available ‘raw’ Street View imagery uploaded to Mapillary and some of the aerial imagery uploaded to OpenAerialMap.

The GPRH's technoscientific approach and its use of advanced technologies were among its most important selling points. However, the adequacy of the program's high-tech approach, which required expensive technical equipment, computational infrastructure, and specialised expertise, can also be questioned. According to a development specialist loosely associated with the program, the use of such advanced technologies in areas marked by deprivation and poverty amounted to "driving a Lamborghini through the slum" (Interview, 13.02.2025). Based on his experience, he claimed that much could already be achieved with "old school" paper-based survey methods, potentially even more because local labour is usually cheap. He also argued that many informal settlements are built in zones with "inherent territorial risks", such as dried riverbeds, where vulnerabilities are largely independent of individual housing characteristics (Interview, 13.02.2025). In such contexts, the fine-grained resolution and analytics offered by the GPRH may well be excessive. A similar techno-pragmatism was expressed by an interviewee from Build Change. He explained that the GPRH's assessments are helpful for planning and politics, but that retrofitting in the end is about doing "the three, four, five basic things that every house needs" for which, "you do not need a lot of high tech" (Interview, 26.03.25, S. 18). He concluded that the technology used by the GPRH and Build Change "is a useful part of the puzzle, but it is just a part of the puzzle. It is not the only thing" (Interview, 26.03.25, S. 19).

The Digitalising Bank: The Mainstreaming of Geospatial Methods through the World Bank

“Our knowledge is our real weapon to fight poverty. Our knowledge—our subject matter expertise on people, prosperity, planet, infrastructure and digital—that’s who we are.”

- Ajay Banga, World Bank President²⁹

With its use of machine-learning algorithms as early as 2017, the GPRH preceded the World Bank’s broadening engagements in data-driven development and AI today. But it is only one of many World Bank programs that engage in data-driven development and geospatial knowledge production. This shorter chapter shows how these mapping methods are circulated through the World Bank’s institutional network and how it relates to its development agenda and paradigms. This shows that the GPRH’s position embedded into the GFDRR and the World Bank’s global operations lend power and traction to the circulation of its mapping methods and algorithms.

This further shows that the program’s geospatial experimentation has effects beyond its institutional boundaries or intended uses for resilient housing. A leading member explained that having proven the feasibility of its methodologies, the program will now focus on “how we can place this into other people’s hands” which is why they “spent some time creating a methodology report, putting some publications together, getting the word out there” (Interview, 23.04.25, S. 21). This geospatial knowledge production has also led to multiple replications of its methodologies by different actors.

The Geospatial Knowledge Bank

This self-proclaimed role of the World Bank as a “Knowledge Bank” goes back to James Wolfensohn, who served as World Bank president from 1995 to 2005. In his famous “Cancer of Corruption” Speech held in 1996, he suggested the unique position of the World Bank as a knowledge broker, whose “relationships with governments and institutions all over the world, together with our unique reservoir of development experience across sectors and countries, position us to play a leading role in this new global knowledge partnership” (Wolfensohn 2005, 52). The unabated power and influence of the Bank in this regard was reiterated by one of my

²⁹ Quoted in the Bank’s ‘Knowledge Compact’ (World Bank 2024, 1)

interviewees, who characterized the Bank as “essentially a huge think tank” which has “a global knowledge leadership”(Interview, 04.06.25, S. 3).

Critical studies have interrogated the Bank’s institutional role as a knowledge broker, which exerts power by financing research, producing data, and circulating reports. Michael Goldman’s book *Imperial Nature* provides a comprehensive critical account of the World Bank’s transformation into a ‘Knowledge Bank’ since the beginning of the century (Goldman 2005). Tracing just some of the many institutional networks, professional fields, and policies in environmental knowledge production, Goldman highlights the World Bank’s leading role in institutionalizing what he terms ‘green neoliberalism’. He ultimately suggests that the branding of the Bank is partly correct: “There are no other equivalent institutions. Knowledge is now its greatest asset, and it is generated and used in highly strategic ways in borrowing as well as lending countries” (Goldman 2005, 179).

In recent years, the paradigms pushed by the World Bank have also shifted towards mainstreaming data-driven development and geospatial tools, and more recently, the embrace of the AI-based tools. The World Bank’s recently published ‘Knowledge Compact’ clarifies the World Bank’s role as a data-driven development organization. The report emphasizes the World Bank’s use of data analytics, for example by suggesting that “machine learning and AI, coupled with satellite and drone imagery, social media and high velocity data, are encouraging new data-driven approaches to project design, remote supervision, results reporting and risk management” (World Bank 2024, 23). It particularly emphasizes the Bank’s use of Artificial Intelligence, which involves the use of “machine learning models” and “predictive analytics” and “analysing remote sensing data” (World Bank 2024, 23). As a response to what it terms the “AI Revolution”, one of its main conclusions is that the World Bank’s will “continue to responsibly expand AI use to accelerate, sustain and deepen development impact using innovative technologies”(World Bank 2024, 2).

The World Bank has been an especially productive agent in terms of geospatial knowledge production. For example, in 2017, it held a ‘Geospatial Day’ with the fitting slogan “from pilot to mainstream,” whose general aim was “further raising awareness amongst Bank consultants and staff of the enabling power of geospatial information and technology”(World Bank 2018a). The institutional centre of this engagement at the Bank is the Geospatial Operations Support Team (GOST) which aims at “creating a set of services and resources to help make geospatial data useful and accessible across the World Bank” (GOST 2018). Members of this team also conducted the GPRH’s very first pilot projects in Guatemala and Dominica, developing the first prototypes of its methodology. Overall, this turn towards technological innovation and the strategic development and accumulation of geospatial knowledge is also reflected in the global

biography of the GPRH. It constitutes a program with a relatively small team and a specialised approach, which nevertheless had a considerable impact by mainstreaming its approach and replicating its methods globally.

GFDRR

The GFDRR has become an increasingly important organization in circulating models for disaster risk management. As noted by Zeiderman, the GFDRR emerged as part of the “globalization of risk management policy” since the late 1990s and partnered with the World Bank in 2006. The GFDRR operated as a key organisation of “a more general shift toward endangerment as a central problem for urban planning, government, and development on a global scale” (Zeiderman 2016, 72). The influence of the GFDRR stems from its embedded position at the World Bank. For example, the head of the GFDRR states in 2021 that: “Inclusive, sustainable, and resilient development is an urgent global priority. With more than a decade of experience in disaster risk management and climate adaptation, GFDRR, from its position within the World Bank Group, is uniquely positioned to meet these needs” (GFDRR 2021a, 7).

A central component of GFDRR’s broader mission is its elaborate use of geospatial information systems, particularly in relation to risk management, across its programs and partnerships. As stated in the GFDRR’s annual report of 2023, the organisation aims to enhance resilience to climate change and natural hazards “through greater access to and adoption of geospatial tools and services” while “developing data, tools, and services that are accessible at low cost and tailored to World Bank operations and client countries”(GFDRR 2023, 16). One program is the Digital Earth Partnership, which aims to foster resilience “by developing and transferring global knowledge, mobilizing key partnerships, and providing operational support to client-executed and Bank activities in the production and use of earth observation for resilience”(GFDRR 2025).

The increasing reliance on geospatial data goes hand in hand with a discursive shift that emphasizes the precision of interventions and the objective of gaining a ‘real-time’ understanding. For example, the report on the GFDRR’s partnership days 2024 emphasizes its “targeted approach in providing technical assistance and funding where it can achieve the greatest impact (GFDRR 2024b, 2). It also notes that “our deep real-time understanding of disaster risk management priorities enables us to match innovative solutions with disaster risk challenges, making us a unique partner to help drive impact at scale” (GFDRR 2024b, 2).

The GFDRR hosts a range of global programs and platforms focused on geospatial data. For example, the ‘Digital Earth’ program focused on earth observation, or its ‘Open Data for Resilience Initiative’ (OpenDRI) platform, which allows for data sharing between different development

projects (OpenDRI 2025). Another important network for knowledge circulation is the GFDRR's 'Understanding Risk' community, a global network focused on risk assessment and communication, hosting biannual conferences since 2010 (GFDRR 2021c, 23). The GFDRR strategy 2021-2025 states that this broader engagement in geospatial data production "has evolved from adapting post-disaster assessment methodologies and developing new methodologies for remote data collection to investing in new analytical research and testing cross-sectoral operational solutions" (GFDRR 2021c, 21). The GPRH is one component of this agenda whose global geospatial knowledge production exemplifies this shift perfectly well.

At the GFDRR partnership days held in 2024, the head of the organisation emphasized the unique position at the World Bank, particularly the symbiotic relationship between donor contributions and technical assistance. He is quoted saying "You won't be able find a partnership like this. [...] There's no other development institution with the size and the reach of the World Bank Group" (GFDRR 2024b, 6). Through the reach and power of the World Bank, the GFDRR emerges as a central institution for geospatial experimentation in the development sector and the corresponding mainstreaming of data-driven modes of urban risk management.

As the case of the GPRH shows, the ability to use targeted technical assistance and tap into development funding channeled through the Bank is a crucial element of this strategy. The head of the GFDRR suggested at an event that "Our deep real-time understanding of disaster risk management priorities enables us to match innovative solutions with disaster risk challenges, making us a unique partner to help drive impact at scale" (GFDRR Partnership Days, 1). This demonstrates that the World Bank, and especially the GFDRR, function as an important 'centres of calculation' for the 'global urban resilience complex' (Webber, Leitner, and Sheppard 2021, 348). Due to their increasing focus on data-driven development and innovative geospatial technologies, perhaps this notion can be taken literally as well.

Replications

The GPRH not only produced housing data but also published the urban mapping and analytics methods it developed. Besides the guidance notes published by the World Bank, which are generally aimed at development practitioners, this involves technical papers in specialised journals. These detail technical procedures that are central to its methodology and workflow: detecting masonry with deep learning image segmentation (Wang, Antos, and Triveno 2021), the fusion of drone and street view imagery (Gosling-Goldsmith et al. 2024), and results from its pilots with large-scale automated assessments of household vulnerability in Colombia and Peru (Wang

et al. 2023). This shows that the program also actively fosters the replication of its methods by sharing its learnings with a broader community of geospatial practitioners.

The GFDRR's Digital Earth program has replicated the GPRH's methodology in the Caribbean and expanded the use of its housing assessment methods to other islands. Data specialists of the GFDRR re-used aerial images collected by the GPRH and updated its rooftop classifications by applying more recent computer vision models for image analysis (Interview, 27.03.25, S. 4). The updated labels and models were then expanded with data collected in Saint Vincent and the Grenadines as part of another GFDRR project. As the responsible geospatial scientist explained, the adaptation went relatively smooth as most methods and workflows had already been developed, tested, and documented, "it was just a matter of updating the models to use the latest state-of-the-art computer vision models"(Interview, 04.06.25, S. 9). As she stated, "the biggest challenge was collecting data for our own context. So, having to label and annotate images that are specific to St. Lucia, to Dominica" (Interview, 27.03.25, S. 4). This indicates that the main contribution of the GPRH must not be seen in the place-specific housing data it produced, but rather in the geospatial knowledge it produced, including the methods, platforms, and workflows it developed.

This has also led other teams within the World Bank to adopt some of the GPRH's methods for their own purposes. An interviewee mentioned that other entities of the World Bank, such as the Digital Earth team, the Poverty team, the Health and Education teams, as well as the Safer Schools Program, have now adopted such methods in their respective sectors (Interview, 04.06.25, S. 7 - 8). These replications were not intended by the program but were enabled by the broader sharing of its technical procedures and practical experience. The World Bank scholar Michael Goldman, has described how the World Bank's institutional structures lend traction to certain forms of development expertise, as tentative procedures of knowledge production gradually become "institutionalized, normalized, and multiplied in local sites through which new forms of knowledge and power now circulate"(Goldman 2005, 175).

Some of the governments supported by the GPRH also continued using the same methods on their own. The 'knowledge transfer' of its geospatial methods was most fruitful in Paraguay and Colombia, where statistical agencies are now systematically combining these assessment methodologies with their own census data (Interview, 04.06.25, S. 9). It was also mentioned that the NGO PLACE, which focuses on providing "high-resolution, high accuracy mapping data for rapidly growing cities in Africa and small island states" has applied the methods for its own mapping efforts (PLACE 2025). This brief overview of replications of the GPRH's methodology is not systematic, and their respective use by other actors depends on their distinct positions.

However, it demonstrates that the World Bank's position as a knowledge bank also fosters the circulation of these 'modes of seeing' beyond the program's formal boundaries and mapping sites.

Discussion: Mapping 'Informational Peripheries' in the Name of Resilience

The settlements targeted by the GPRH are vastly different urban settings, ranging from the metropolitan Breña district in Lima to small 'slums' on the Island of Sint Maarten, and even the entire coastal city of Padang in Western Sumatra. Government officials commonly designated these places as 'areas of interests' for mapping because of a lack of information about their housing stock. These sites are therefore perfect examples of 'informational peripheries' due to being spaces "marked by both geographic and informational distance from the state" (Datta and Hoefsloot 2025a, 3). Focusing on the GPRH's experimental mapping of these settlements, this thesis foregrounded the dynamic process by which these heterogeneous urban environments became "experimental testbeds of new smart technologies for visualisation, mapping and urban governance" (Datta and Hoefsloot 2025a, 3).

This chapter relates the main findings from my empirical research to the conceptual framework and embeds them within the existing literature. It thereby answers the overarching research question of how the GPRH targets disaster-prone informal settlements as experimental testbeds for geospatial technologies in the name of resilience? Doing so, it reflects on the implications of the World Bank's facilitation of such mapping methods for the urban governance of 'informational peripheries' (Datta and Hoefsloot 2025c).

Main Findings

The first chapter characterized the GPRH's approach to 'resilient housing', which blends anticipatory disaster management, housing improvement, and geospatial experimentation. Claiming that governments lack reliable information on the quality of their housing stock, the program uses advanced geospatial technologies to produce fine-grained housing data on informal settlements. The GPRH directly contrasts its remote sensing methods with 'traditional' manual housing surveys by highlighting the cost-efficiency, objectivity, and scalability of its approach. The program persuades governments to reform housing programs and shift their targeting toward disaster-prone areas and low-income populations. It does so by framing disasters as preventable tragedies and portraying substandard housing as a matter of life and

death, thereby shifting towards anticipatory disaster management and 'Building Better Before'. This provides a key justification for the program's predictive mapping of informal settlements, conducted by its technology component. These housing assessments from the sky and street generally constitute the first step in the program's engagements and serve to estimate retrofitting costs and prioritize further interventions. In the program's central countries of engagement, Mexico, Colombia, and Indonesia, this housing data production was flanked by extensive policy advocacy and technical assistance from Build Change.

The second chapter demonstrated how the GPRH operates through technical assistance partnerships with the World Bank. This position provides considerable resources and flexibility and fundamentally shapes the geography of the program's operations. The program negotiates with client governments about where and how to apply its methods but is also guided by its broader agenda and research interests. While the program's multi-view urban observation methods were primarily designed for assessing housing resilience, its geospatial methods have taken on a life of their own, as the program "branched and zigzagged and applied the technology to various types of projects in various sectors" (Interview, 23.04.25, S. 6). The methodology was continuously adapted to different contexts and government interests: assessing rooftops and locating informal housing in the Caribbean; improving cadastral and taxation systems in Lima; conducting large-scale property valuation in Colombia; and assessing road safety in Bogotá and Padang. The multi-purpose nature of the methods and data produced by the GPRH perfectly showcases the experimental nature of its geospatial interventions.

The third chapter examined how the GPRH's technical procedures and workflow translate urban materiality into digital data and legible risk maps. It showed the sociotechnical infrastructures and labour necessary to conduct these mapping missions. This involves elaborate planning for data collection as well as the repetitive manual labelling of thousands of images needed to train machine learning models. Combining imagery from the sky and the street, the GPRH facilitates the digital legibility of informal settlements down to the scale of individual housing units. The outputs include preliminary cadastral maps derived from drone imagery and predictions regarding the physical characteristics of houses from Street View. The predictions from the machine learning models are compiled together and stored as unique 'housing passports' for each house. The program also designed an interactive 'housing portal' to visualize the housing data on the neighbourhood scale for different users. Overall, these technical procedures achieve a platformisation of informal housing, which enables new fields of governmental intervention.

Finally, the GPRH's methodological innovations and practical experiences were systematically documented in reports, guidance notes, and scientific articles, enabling the replication of its

geospatial methods. Through the World Bank's institutional ecosystem and the GFDRR, these methods circulated further and were adopted by other Bank teams, census agencies, and subsequent development projects.

These findings show how the GPRH facilitates the digitalization of informal settlements to support their incorporation into housing policies and governance. Providing assessment tools and knowledge, the program conducts geospatial interventions that produce housing data and render housing units into digital objects of prediction and data-driven governance. Circulated through the World Bank institutional systems, such technoscientific modes of seeing, classifying, and measuring the built environment have the potential to rapidly transform the governance of 'informational peripheries'.

Conceptual Framework

The GPRH selectively targets urban peripheries across Latin America, the Caribbean, and Indonesia in the name of resilience. The GPRH conducts these mapping missions as part of the World Bank's technical assistance to local governments. These geospatial interventions produce fine-grained housing data using methods not readily available to most client states. While the digitalisation of the targeted settlements is implemented in coordination with the local 'digitalising state' (Datta 2023), it is primarily driven by the World Bank's research interests and global development agenda. This illustrates well that "digital technologies of the state are produced through networks of state and non-state actors" (Datta and Hoefsloot 2025a, 12). Many of the mapping projects discussed in the thesis form a hybrid assemblage that can involve multiple development programs, private geospatial companies, and third-party development funding. The Bank's recent push towards building geospatial capacities, therefore, also shapes emerging geographies of the digitalising state.

Many of the GPRH's mapping missions were embedded into the World Bank's broader development agenda and coupled to housing policy reform and housing programs. The program can therefore be seen as an instance where digitalisation and automation "are as much entailed in detailed operations of bureaucracy and implementation of policy as they are outcomes of external 'rupture' through rapid technological developments led by big tech" (Datta and Hoefsloot 2025b, 282). The GPRH's methodology does not just diagnose the physical condition of informal settlements, but also serves to transform marginalised peripheries "into spaces that are increasingly visible, mapped, calculable and programmable" (Datta and Hoefsloot 2025c, 1). These forms of geospatial knowledge are thus inseparable from the Bank's global role as a 'knowledge bank' and powerful financial institution. These observations underscore the need to

examine the broader political constellations in which the digitalization of ‘informational peripheries’ occurs, as well as the ways data is mobilized to advance further structural transformations.

Zeiderman has called for close attention to “the particular, and sometimes unpredictable, ways that techniques for securing cities are assembled and deployed in specific locations” (Zeiderman 2016, 206). The GPRH forms as a horizontal network through which such techniques are circulated and re-adapted across different urban settings. Through the World Bank’s technical assistance partnerships, the program grafts itself onto a variety of urban environments, mobilizing its institutional position to produce comparative geospatial knowledge. It therefore deliberately targets disaster-prone settings to conduct ‘situated experiments’ in the name of resilience.

Sara Safransky, has argued that “understanding the traction and power of algorithms thus involves interrogating the epistemologies on which they are based and conversely, those that they exclude” (Safransky 2020, 206). The drone images produced by the GPRH offer higher resolutions than other remote sensing methods, and Street View provides a ‘grounded’ horizontal perspective that can offer a ‘sense of place’ (Cinnamon 2024). However, the program treats these settlements as geophysical landscapes to be scanned using standardised methods, rather than as unique social habitats shaped by everyday practices. Unless complemented by other forms of spatial knowledge production (Borie, Ziervogel, et al. 2019, 7), such fine-grained data production systematically misses the social and cultural dimensions of these urban spaces.

The program embraces technoscientific modes of seeing for urban governance. Its predictive mapping is based on a positivist, data-driven epistemology, implicitly assuming that more data automatically lead to better urban governance. As a result, the program presents its remote sensing and algorithmic methods as superior to manual house-to-house surveys and explicitly frames social interactions as sources of bias to be avoided. This obscures the fact that, unlike house-to-house surveys,³⁰ there is no deliberation with inhabitants about their needs and priorities at any point in the GPRH’s workflow. Similar to other GIS-based techniques of slum management, this constitutes a mode of ‘governing at a distance’ (Richter and Georgiadou 2016), which shies away from social interactions, instead of treating them as productive and necessary encounters with epistemic value in their own right.

³⁰ Drawing on his participant observations of risk assessments in the urban peripheries of Bogotá, Zeiderman described how “government technicians are drawn into repeated interactions with inhabitants of these areas”, arguing that the outcomes of “such assessments depend on how both groups engage in the sometimes collaborative, sometimes contentious process of codifying the world in terms of risk (Zeiderman 2016, 81).

Previous research has shown how digital platforms used for market value assessments or predictive crime mapping perpetuate algorithmic violence by automating racialized value judgments that lead to discriminatory classifications of urban space (Jefferson 2018; Safransky 2020). While the algorithms used by the GPRH are not the typical “harmful algorithmic assemblages” described by Safransky, they can still have unintended consequences and reproduce existing inequalities (2020, 206). Tracing the material effects of such algorithmic governance of informal housing would have required deeper contextual research. However, the selection and classification of houses for subsidies or retrofitting are partly delegated to aesthetic judgments made by machine learning models, making the process very superficial and opaque. Furthermore, the rapid nature of the program’s housing assessments, sometimes conducted in just a few days of ‘fieldwork’, largely excludes local, contextual knowledge about these places, which can be seen as a form of “epistemological violence” (Safransky 2020, 213).

As Safransky highlights, “the outputs of algorithms reflect the politics of the data that are put into them” (2020, 216). The GPRH’s methodology generally builds on an extractive model of data collection, which promises to guide precise, cost-efficient interventions to mitigate the loss of assets and lives estimated to be at risk. The ‘areas of interest’ are mainly selected for strategic government interests, to render these spaces legible for governance and private actors, and to reduce contingent liability in the event of a disaster. While the reprioritization of housing policies and retrofitting efforts towards the urban poor undoubtedly have many positive effects, this represents a distant, technocratic approach to urban governance in which spatial data and expertise are centralised. Following Foucault, these populations are seen “not from the standpoint of the juridical-political notion of subject, but as a sort of technical-political object of management and government” (Foucault 2009, 70).

The Global Resilience Complex

The GPRH advances its own version of ‘housing resilience’ by providing governments with geospatial technologies and assessment methods, as well as by circulating technical guidance notes and other knowledge products. Its multi-sited operations and knowledge-based interventions are therefore paradigmatic for programs associated with the ‘global urban resilience complex’ (Webber, Leitner, and Sheppard 2021). As part of the World Bank and the GFDRR, the program is organized through “a network of key organizations”, operates through “a set of measurement, assessment, and institutionalization techniques and procedures” and mobilizes “experimental discourses and practices that seek to marketize urban resilience” (Webber, Leitner, and Sheppard 2021, 344). At the centre of this global complex “is the development of technologies to assess, measure and implement urban resilience” pushed by various

organizations, which “signal the attempts by these actors to produce universal best practices and models of urban resilience”(Leitner et al. 2018, 1278). The GPRH’s universal methodology for ‘rapid housing assessments’ is part of the same family as other geospatial tools circulated by the GFDRR, such as the ‘CityStrengthDiagnostic’ and ‘CityScan’. Tracing the application of this methodology across different sites also revealed the continuous re-adaptation to distinct urban environments, unique partnerships, and strategic government interests. This productive tension between technocratic universalism and earthbound situated experimentation is a driving factor of the GPRH’s operations and paradigmatic of urban governance in the Anthropocene as a whole (Wakefield 2021).

As the GPRH’s geospatial interventions operate through the World Bank’s technical assistance to client governments across the Global South and can be seen as a form of ‘Green Structural Adjustment’(Bigger and Webber 2021). They target the municipal scale and are flanked by broader policy reforms and capacity building. This technical support supports the preparation of subsequent loans and large-scale housing projects, leveraging the World Bank’s conditional power as a global financial institution. The program’s production of fine-grained data on urban environments most closely aligns with the observation by Bigger and Webber that such projects frequently advance the use of “sophisticated environmental data to plan urban resilience projects” (Bigger and Webber 2021, 37). The intermediate mode of operation, by providing knowledge, expertise, and technical tools, makes it important to consider the positioning of different actors in data and knowledge production on ‘urban resilience’ and to analyze the epistemic dimensions of such interventions.

The GPRH’s operations are embedded in the World Bank investment policies and aim to prioritize investments, prepare loans, and channel international funding. According to its annual report of 2017, the GFDRR “will increasingly focus on advancing resilience at the municipal level by developing methodologies for prioritizing investments, promoting relevant policy reforms, and advising sub-national entities in identifying methods of leveraging private capital toward resilience investments” (GFDRR 2017, 8). The GPRH advances this broader agenda by facilitating the legibility of informal settlements, down to individual houses, which enables the ‘packaging’ of interventions and the estimation of retrofitting costs on a larger scale. These geospatial interventions are never merely about the knowledge and data produced, but also about inducing broader policy changes and municipal reforms across different contexts (Hilbrandt 2025). Similar to other Bank programs that cultivate the ‘investability’ or ‘creditworthiness’ of cities across the Global South (Bigger and Webber 2021; Grubbauer and Hilbrandt 2023), the GPRH’s geospatial experimentations also advance financialization of the low-income housing sector (Grubbauer

2020; Grubbauer and Escobar 2021). This data production also advances the World Bank's role in structuring and procuring finance for large-scale housing projects and enables the expansion of microfinance into low-income housing markets.

The GPRH's methodology can be understood as a multi-view urban survey designed specifically to assess rooftops and facades. In contrast to topographic or cartographic surveys, the combination of drones and Street View enables automated visual assessment of built environments and urban streetscapes. As Martin Dodge projected, Street View technologies have the potential to facilitate "novel analysis-based algorithmic inspection and automated detection of environmental characteristics of place" (Dodge 2018, 955). Such visual assessments lead to distinct processes of enclosure that differ from previously studied cadastral mapping or drone surveys alone (cf. Cowan 2025b; Emmenegger 2022). The deployment of such urban observation technologies in the name of resilience thus has the potential to transform urban governance and property management in unpredictable ways.

The GPRH developed a multi-purpose toolkit for sensing, assessing, and classifying urban space. The same instruments and workflows used to assess 'resilience' and identify vulnerable houses for housing retrofitting can be easily repurposed for mass property valuation or taxation. Similar to the drone surveys examined by Thomas Cowan, the digital mapping procedures of the GPRH constitute the first step toward both the assetisation and platformisation of informal housing (Cowan 2025a). First, in alignment with the discursive construction of informal housing as an asset class to be protected, the program's methods are employed as a 'valuation practice' to estimate property values (Birch and Muniesa 2020). Second, the technical procedures employed by the GPRH transform these houses into digital objects with unique identities to be managed and visualized on property platforms, thereby facilitating their legibility for governmental interventions. The multi-purpose nature of the data produced points to an underlying problematic of the datafication of development (Taylor and Broeders 2015). To some degree, the stated purpose for which this housing data is collected does not matter; in creating material imprints of urban space, some form of legibility is always produced. Whether this visibility amounts to the well-meaning gaze of a 'protective eye' depends (World Bank 2021), or is seen as an intrusive form of surveillance, as always, depends on perspective.

The GPRH's workflow requires capturing urban images from different angles and establishes a standardised, replicable protocol for analysing them using machine learning. While both are based on aesthetic criteria, the GPRH's methods for assessing urban space differ from the quick, explicitly subjective 'windshield surveys' described by Asher Ghertner (Ghertner 2015, 206). These technical procedures operationalise certain aesthetic norms of what 'resilient housing' is

expected to look like and can be applied at scales. While the relevant criteria are initially co-designed with engineers, the fusion of training data from different sites and the continuous training of new models (sometimes based on outputs of other models) obscure exactly how such automated assessments arrive at their conclusions. While these assessments are implemented in a highly selective manner, this mode of classifying urban space through machine vision and algorithms may well constitute “another shift in the calculative foundation of government” specifically targeting informal urban spaces (Ghertner 2010).

Ultimately, the GPRH exemplifies how the assessment tools circulated through the ‘Global Urban Resilience Complex’ also shape the governance of ‘informational peripheries’ by experimenting with geospatial technologies that render them hyper-legible to techno-political management, while still essentially sustaining their political marginalisation. Many of the pragmatic ‘pro-poor’ arguments used to frame the GPRH are hard to dispute, and the program has brought about material improvements through its global engagements. The policy shift to housing improvement and retrofitting, and its arguments for supporting the urban poor *before*, rather than *after*, the next disaster, do hit home. However, if ‘resilient’ housing becomes a synonym for ‘datafied’ housing, and as long as the World Bank continues to flank its geospatial interventions with microcredit schemes aligned with its ‘financial inclusion’ agenda (Grubbauer 2020), there are many side effects of this datafication that warrant more critical inquiry. The question, therefore, remains of who benefits from the ‘co-benefits’ of such geospatial interventions in the name of resilience.

Methodological Reflection

Drawing on methods from policy mobilities to ‘Follow the Development Program’ was essential to grasp the full scope of the GPRH’s diverse engagements in Latin America, the Caribbean, and Indonesia. This methodological approach somewhat mirrored the operations of the GPRH itself. It recognized the adaptive nature of the program’s engagements and enabled me to draw comparative insights from its work across vastly different contexts. Similar methods could be used to trace many other multi-sited programs and partnerships hosted at the World Bank.³¹ On the other hand, the sprawling nature of my data collection posed both methodological and conceptual challenges. In countries where the program’s engagement was most extensive, it was difficult to distinguish between local policy traditions and the contributions by the GPRH. This was partly rectified by focusing on the technology component. This component of the program was

³¹ Potential candidates could be the ‘City Resilience Program’ (<https://www.gfdr.org/en/crp>), the ‘City Planning Labs’ (<https://collaboration.worldbank.org/content/sites/collaboration-for-development/en/groups/city-planning-labs.html>), or the ‘Global Smart City Partnership Program’ (<https://www.worldbank.org/en/programs/global-smart-city-partnership-program>), to name just a few.

more stable across different sites and particularly well documented by the GPRH. Nevertheless, the frequent re-adaptations and changing contexts yielded heterogeneous empirical findings that were hard to combine into a single conceptual framework and risked making the study overly broad.

The technical reports published by the GPRH provided detailed insights into the program's inner workings and were crucial to understanding its operations and rationales. Relying on interviews with development specialists and official reports as my primary sources, my empirical perspective was mediated through the World Bank's own institutional systems and documentation practices. This partly reproduces the gaze of this powerful global institution along with the gaps and limitations embedded in its production of development knowledge. The complementation of these findings with other qualitative methods would have likely produced a different perspective.

Further Research Avenues

The case of the GPRH opens up multiple avenues of further geographical research. It remains an open question how exactly GPRH's engagements have shaped housing policies and programs in specific countries of engagement, particularly in Mexico, Colombia, and Indonesia. This especially relates to the GPRH's often-stated objective to expand private-sector participation and (micro-)finance in the substandard housing sector. Building on the concept of 'informational peripheries', further research could explore in a more grounded way how the production of such housing data transforms urban governance and existing property systems. Despite the GFDRR's central position within the 'global urban resilience complex' (Webber et al. 2021), surprisingly little scholarship has examined this organization directly. There would be value in studying its approach to the mainstreaming of disaster risk management and its circulation of geospatial tools.

Conclusion: Operationalizing Informal Housing

The GPRH employs visual sensors mounted on drones and cars to capture urban environments and extract information from them. It therefore adopts technoscientific modes of seeing into development practice and urban governance. Media scholar Lisa Parks has argued that populations of certain regions have become a targeted class monitored by drones, "simply because they live and move in areas in which terror suspects may operate" (Parks 2016, 231). In the case of the GPRH, they become so because they live in disaster-prone areas and are seen as "lives at risk" (Zeiderman 2016, 60). Without inflating the differences between the use of drones

in global warfare and in the development sector, the similarity is that both applications build on the promise that such “prosthetic devices” (Haraway 1988, 583) can guide efficient, almost surgically precise interventions into (urban) space, even from continents away.

On the Mapillary platform, where the GPRH uploaded its Street View images, even most capital cities are only mapped in fragments; however, in the ‘areas of interest’ targeted by the program, almost every alley can be fully explored in 360°. This selective hyper-legibility is conditioned by the GPRH’s flexible, multi-sited mode of operation. It also reflects the World Bank’s strategic research interests as a global knowledge institution that experiments with data-driven governance in the Global South. The existence of these images is also co-reliant on the algorithmic assemblages and sociotechnical infrastructures that the GPRH developed to process them into legible formats. These ‘conditions of possibility’ for these images to exist show that the GPRH’s geospatial technologies must be seen as “active perceptual systems, building on translations and specific ways of seeing, that is, ways of life”(Haraway 1988, 583).

The urban imagery collected by the GPRH differs from other representations of urban space, such as maps or plans, used for governance, because these images are strictly non-representational. While they are shared online and can be viewed by human eyes, they primarily serve as a mundane intermediate product in the program’s workflow. A technician told me that the large volumes of Street View imagery is “hard to digest” because “when you open up a folder, it is just photos, photos, photos, photos... It is not so easy for them to be of use unless they are streamed into a platform” (Interview, 23.04.25, S. 15). This makes them a perfect example of operational images, defined by media scholar Jussi Parikka as “images that exist only because of other operations“ (Parikka 2023, xi). Without the digital labour, platforms, and algorithms that constitute the sociotechnical infrastructures of the GPRH’s methodology, these images would be next to useless for the systematic governance of these urban spaces. Just as they also would not exist without the World Bank’s global operations.

In that sense, the GPRH did not merely map these ‘informational peripheries’ but developed technical procedures to operationalize these ‘illegible’ urban spaces and stream them into digital housing platforms. This is also what makes these methodological procedures and chains of operations so adaptable to other purposes. The program’s operationalisation of ‘informational peripheries’ was legitimized in the name of building resilience but also driven by the desire to connect these spaces to data and capital circuits and to integrate them into digital property systems.

The millions of urban images produced by the GPRH also reflect a fundamental dilemma of data-driven governance. The huge volumes of data generated in cities around the globe have quickly grown too large to be sorted, processed, and analysed by human labour alone. Development actors such as the World Bank frame machine learning and AI tools as a resolution to this issue and increasingly mainstream automated analytical and decision-making capabilities. While enormous volumes of urban data are made freely available through open access formats, many deeply entrenched inequalities persist. Just because urban data is openly accessible does not mean it is inclusive or emancipatory. It is not just about who has theoretical access to geospatial data, but about who has the power and capacity to process and act on this data. Furthermore, the 'black boxed' and 'high-tech' nature of these 'smart' technologies creates new challenges and dependencies, raising a range of ethical and political questions about the technocratic automatization of decision-making processes.

The GPRH developed technical procedures for capturing, abstracting, and analysing urban materiality to enable governance from a distance. How can the sociotechnical chains of operations that constitute such mapping processes be remoulded to enable participation, dissensus, and critique from those who are targeted and affected by them (cf. Kaika 2017)? The hegemonic paradigm of data-driven development systematically sidelines such questions, privileging technocratic monitoring and marketization over the 'inefficiencies' of political deliberation. Likewise, the push for rapid, cost-efficient, and socially distant data collection frequently obscures the historical conditions and social relations that produce the very conditions subjects are expected to become resilient to.

Technoscientific modes of seeing, classifying, and valuing the urban environment are likely to reformulate how the state and other actors address 'informational peripheries' in the future. Returning to Donna Haraway, the ultimate question is what ways of life these maps cultivate.

Personal Declaration

I hereby declare that the submitted thesis is the result of my own, independent work. All external sources are explicitly acknowledged in the thesis.

I hereby also acknowledge the 'algorithmic assemblage' that assisted me during the writing process: Grammarly was used to assist in text editing. DeepL was used to assist in the translation of Spanish reports. ChatGDP was sporadically used with specific prompts to selectively improve grammar and wording.

Prompt example: "I do not like the beginning of this sentence. How can I rephrase this without changing the meaning?"

A handwritten signature in black ink, appearing to read 'C. Jung', with a stylized flourish at the end.

Christian Jung, 30.11.2025, Zürich Höngg

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Annex 1: Research Brief



THE RISK-MAPPING OF INFORMAL SETTLEMENTS AND THE WORLD BANK'S GEOSPATIAL KNOWLEDGE PRODUCTION

MASTER THESIS IN URBAN GEOGRAPHY

„Urban resilience“ has become a pivotal concept in global development discourse and practice, especially in the context of disaster prevention and climate change adaptation. Parallel to this emphasis on resilience, the World Bank (WB) has increasingly repositioned itself as a 'Knowledge Bank' since the turn of the century. This paradigm shift brought changes in how the WB's technical assistance programmes are designed and locally implemented. In many recent projects, the WB directly supplies technical means and methods of knowledge production about various topics of developmental concern.

In my master thesis, I take a closer look at an innovative World Bank development program at the intersection of these two broader developments: the [Global Program for Resilient Housing](#) (GPRH).

The GPRH has been running since 2018 and focuses on cities in Latin America and the Caribbean. The program carries out the mapping of informal settlements in disaster-prone areas and has developed a method which allows for structural assessment of their physical conditions based on Machine Learning. This allows for targeted housing retrofitting and better governance of the targeted settlements. Thereby the GPRH represents ongoing effort to achieve more disaster resilient housing.

The program offers a suitable vantage point to study why urban mapping has become a central focus of the World Bank and how the geospatial knowledge produced is utilized for disaster prevention and development.

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www.urbanclimatefinance.org

Annex 2: Interview Guides

Note: *Based on my background research and preparation, the Interview guides were tailored to the position and technical expertise of the respective interviewee. For example, by asking questions about specific projects they were engaged in, or topics they wrote about, or their role in the workflow (e.g. drone pilot, data analyst). This template is intended to give a broad description of my general approach to the interviews, not as a definitive, standardised guide.*

Due to time restraints and/or redundancies, usually not all the (sub-)questions were asked. Sometimes I also asked spontaneous follow-up questions when the interviewee discussed particularly interesting topics.

Interview Guide: World Bank Specialist

First, thank you for agreeing to this interview! The purpose of these interviews is to speak with experts in urban development and resilient housing to learn more about the World Bank's engagement in the housing sector in Latin America and the Caribbean. My focus is on the Global Program for Resilient Housing and its use of urban mapping methods.

Before we start, I wanted to ask you if you consent to the recording of this interview for later analysis. I will anonymize the data before using it and not quote your name directly.

- **Introduction**

- You work as a [position] and are involved in multiple World Bank urban development projects. Can you briefly introduce yourself and give some insights into the work you currently do in this position?
- Could you tell us about how the GPRH's approach was initially conceived? What events, problems, or developments were you mainly inspired by?

- **Main Questions**

- The GPRH is part of the GFDRR and operates as one of the World Bank's technical assistance programs. Can you explain how these partnerships are organized?
 - *Can you describe the collaboration with local governments and partners where you applied your approach?*
 - *How were these projects funded?*
- In which cities or contexts did you have the most success with the program? And where was the implementation particularly challenging?
 - *How were test cases and sites (such as the pilot in Oaxaca) selected?*

- *Could you describe some of the main outcomes of the program?*
- Besides mapping, the GPRH also addresses housing policy, technical assistance, and supports private sector participation. Could you talk about the components of the GPRH and how the housing assessments, policy recommendations, and market-building complement each other?
 - *In which countries or cities were policy changes implemented or the integration of private sector actors particularly successful?*
- How has your approach changed since the beginning of the GPRH? Did the program have a wider impact on the WB's approach to informal housing and urban resilience?
- The data collection methods are quite well documented in the technical guidance notes, but I did not find that much information about what happened with the data afterwards. Could you explain how the data was used?
 - *Did the local governments take over ownership of these data, or was the data also shared other actors?*
- The GPRH conducted multiple pilot projects to test out the feasibility of these new methodologies in informal settlements. Now that the program has been running for some years, were some of these assessment methods also replicated in other settings or by different actors?
- The collection of cadastre data also ties into questions of property regularization, which connects to ideas that have been laid out by Hernando de Soto about the importance of formalization and property rights. Have these ideas also influenced your work with the GPRH? How does the mapping fit into this process?
- What are some of the current activities of the GPRH, and how do you see the program developing in the future? Are there any future mapping missions planned?

- **Concluding Questions**

- What were some of the biggest learnings from the work with the GPRH for you? What are some of the challenges that remain?
- Many of the technological innovations you took up, such as drones, Street View, AI, have gained further traction. Are there any technological trends you think are going to become more important for your work in the housing sector in the future?
- We are now almost at the end of our interview. Is there something that you would like to add regarding what we talked about, or anything that you find of particular importance?

Interview Guide: Technical Specialist

First, thank you for agreeing to this interview!

The purpose of these interviews is to speak with experts in urban development and resilient housing to learn more about the World Bank's engagement in the housing sector in Latin America and the Caribbean. My focus is on the Global Program for Resilient Housing and its use of urban mapping methods.

Before we start, I wanted to ask you if you consent to the recording of this interview for later analysis. I will anonymize the data before using it and not quote your name directly.

- **Introduction**

- You worked as a [position] for the GPRH and were responsible for [role in workflow]. Can you briefly introduce yourself and give some insights into the work you do/did in this position?
 - *Can you describe the daily work you did for the program, and the workflows you were part of?*
- Could you briefly explain how the Bank's urban development projects are usually organised and how specialised technical expertise such as yours is integrated?
- Could you tell us about how the GPRH's technical methodology was initially conceived? What events, problems, or developments were you mainly inspired by?

- **Main Questions**

- The GPRH produces fine-grained imagery that allows structural housing assessments from different perspectives. How does this data and its analysis differ from previous survey methods and datasets?
 - *Are there also instances where the availability of such data can have adverse effects?*
- The GPRH's methodology was adapted in different sites of the project, for example, to hurricane risks in the SIDS, or to assess road safety. Can you explain how these changes in the program's initial focus occurred?
 - *What was the rationale behind this adaptation? What were some of the main learnings of applying the methodology to other sectors?*
- The World Bank has recently taken a lead role in using geospatial data in different sectors. How would you situate the GPRH in relation to other geospatial programmes of the World Bank (e.g. GOST, Digital Earth, CRP)?
- Were you also involved in data collection on the ground? Can you talk a bit about how data collection was organized and what some of the challenges were?
 - *How were the targeted areas chosen? Was there anything that particularly attracted the program to these sites?*

- *Have there been any tangible results of improvements in the cities you mapped?*
- *What are ethical considerations to be made when capturing and/or processing such imagery? e.g. about privacy or regarding potential misuse of these datasets? How did you navigate this in different contexts?*
- *What are the practical limitations to applying such risk-mapping on larger scales?*
- The GPRH conducted multiple pilot projects to test out the feasibility of these new methodologies in informal settlements. Now that the program has been running for some years, were some of these assessment methods also replicated elsewhere?
- What are some of the current activities of the GPRH, and how do you see the program developing in the future? Are there any future mapping missions planned?

- **Concluding Questions**

- What were some of the biggest learnings from the work with the GPRH for you? What are some of the challenges that remain?
- Many of the technological innovations you took up, such as drones, Street View, and AI, have gained further traction. Are there any technological trends you think are going to become more important for your work in the housing sector in the future?
- We are now almost at the end of our interview. Is there something that you would like to add regarding what we talked about, or anything that you find of particular importance?