Building Capacity for Disaster-Resilient Housing: Investigating Less Frequent Hazards in Multi-Hazard Environments

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RESEARCH PROBLEM STATEMENT

Most of the world's housing is built through informal construction processes, where homeowners either self-build or hire builders to construct houses that meet their needs and available resources (Feliciano et al. 2022). This informally constructed housing is often built to add resilience to hazards that builders have been exposed to, reflecting their hands-on training and contextual experience. Yet, in multi-hazard regions, different hazards affect structures distinctly and the knowledge that builders have accumulated over time may not account for less frequent but severe disasters.

In fact, researchers have noted cases of builders who, while aiming to construct housing that is safe in hazards they commonly encounter, inadvertently create structural vulnerabilities that make housing unsafe in hazards they experience less frequently (Audefroy 2011; Goldwyn et al. 2022a). For example, builders who are more often exposed to hurricanes than earthquakes in the Caribbean may learn to construct reinforced concrete housing with open-ground-story first floors. While their resulting housing may be resilient in hurricanes and able to withstand storm surge damage, open-ground-story housing can be vulnerable in earthquakes when not built with appropriately engineered reinforcement (Murray et al. 2022).

With the added challenges of building safer, disaster-resilient housing in multi-hazard regions amid growing global disasters, many researchers and agencies have urged for increased capacity-building to encourage safer housing design and construction (Wisner et al. 2014). Yet, there are few studies showing how to intervene in areas where perceptions and engineering assessments of housing safety may misalign and lead builders to informally construct unsafe housing that they perceive to be safe.

In this study, we discuss misalignments between perceptions and engineering assessments of housing safety in a multi-hazard region, focusing on safety in hazards that builders are less frequently exposed to. Then, we discuss opportunities to intervene in these misalignment areas to build technical construction capacity.

RESEARCH METHODOLOGY AND APPROACH

Context

Our work builds off of prior work by the authors on misalignments between perceptions and engineering assessments of housing safety in Puerto Rico, a US Caribbean island exposed to both hurricanes and earthquakes and where most housing is constructed informally (Clancy et al. 2020; Hinojosa and Meléndez 2018). Puerto Rico was devastated by Hurricanes Irma and Maria in 2017, which damaged or destroyed over 400,000 houses (Brown 2018); a series of earthquakes

and aftershocks from late 2019 to early 2020 that damaged or destroyed another 10,000 houses (Miranda et al. 2020); and most recently by Hurricane Fiona in 2022 (Diaz 2022). Notably, the 2019-2020 earthquakes in Puerto Rico was the first series of devastating earthquakes and aftershocks to damage and destroy housing in Puerto Rico for over one hundred years. These earthquakes increased builder and homeowner interest in learning about earthquake-resilient housing (Goldwyn et al. 2021).

Research Methods

We surveyed over 300 builders and hardware store employees across Puerto Rico to investigate the housing safety perceptions motivating informal housing construction processes in Puerto Rico (Goldwyn et al. 2022b) and then compared those perceptions to engineering assessments of housing safety in wind and seismic events (Lochhead et al. 2022; Murray et al. 2022) to identify where perceptions and engineering assessments did not align and the reasons for those misalignments (Goldwyn et al. 2022a).

To investigate methods of intervening in these misalignments and building capacity, we interviewed 16 individuals familiar with community hazard preparedness in Puerto Rico, including staff from local community-based organizations, international non-governmental organizations, and other individuals involved in community-based hazard preparedness planning in Puerto Rico. We asked interviewees general questions about effectively communicating technical construction recommendations to builders in Puerto Rico as well as more specific questions focused on each of the identified misalignments (i.e., "*Could you describe any strategies you would recommend to a local organization trying to train builders about the safer construction sequence for reinforced concrete and masonry structures?"*).

We transcribed, translated, and then qualitatively coded the interviews in QSR NVivo to identify key themes for how to effectively intervene in misalignments to build technical construction capabilities for earthquake resilience. We used a combination of deductive and inductive coding, first coding in accordance with predetermined codes from literature and then coding additional themes as they emerged. For example, we created one deductive code based on our literature review showing the importance demonstrations have in showing evidence of the benefits of changing one's practices (Dearing 2009). We created additional inductive codes to capture ideas like the need to ensure communities are empowered and encouraged to participate in dialogue, rather than simply lecturing information through one-way information dissemination.

KEY FINDINGS

We identified three areas where builders' perceptions did not align with engineering assessments of earthquake-resilient construction, including perceptions of the heaviness of reinforced concrete slabs, confined and infill masonry, and columns supporting open-ground-story buildings (Goldwyn et al. 2022a). These misalignments represent topics that homeowners and builders in Puerto Rico had expressed concern about during prior data collection, particularly during fieldwork completed six weeks after the 2019-2020 earthquakes (Goldwyn et al. 2021).

Interviewees expressed desire for capacity-building to address the identified misalignments and increase disaster resilience in Puerto Rico. While all the interviewees either knew of or were employed by organizations training individuals on safer housing construction for hurricanes, no interviewees could list an organization or government agency training communities or builders on safer construction for earthquakes. As one interviewee who runs an organization training builders on safer housing construction for hurricanes argued, *"There's room for improvement in the area of earthquakes, especially after going through the [2019-2020] earthquakes… People are more aware that we need to build better houses, and there were lots of concrete structures that were lost to [the earthquakes]... I think there's space for people to learn how to build a structure that is earthquake resilient."* Thus, we document a gap in training needed to address the three misalignments we identified in our prior work (Goldwyn et al. 2022a) to increase the resilience of Puerto Rico's informally constructed housing in future earthquakes.

Generally, interviewees discussed several key ideas that should be considered when aiming to address misalignments and communicate technical recommendations in Puerto Rico, which largely aligned with communication literature. When asked about what components of such a communication strategy could make it more effective in Puerto Rico, 16 (100%) of the interviewees emphasized the need for all communication to be done in Spanish, 15 (94%) of the interviewees explained the need to partner with trusted local leaders, 8 (50%) stated that local leaders should lead all communication, 11 (69%) emphasized the need to connect with community members and listen to their concerns prior to intervening in practices, 10 (63%) explained that information should be simplified and visual to ensure illiterate populations could benefit from recommendations, 9 (56%) mentioned that lecture-style presentations should be complemented by hands-on learning opportunities, and 6 (38%) mentioned the need for demonstrations to illustrate ideas.

When asked about one particular misalignment (builders not perceiving confined masonry to be safer than infill construction practices in earthquakes), one interview working with communities on hurricane-resilient construction explained, *"Well, I haven't heard of any training about that, and it seems like such a small detail, but I bet, you know, from what I hear and from what I expect, that it makes a big difference."* That interviewee then went on to describe some ideas for a small booklet that would inform people of the difference between infill and confined masonry, explaining *"that kind of material is useful, like a general guidance about the little things that can confuse people or overwhelm people."*

Another interviewee emphasized the importance of addressing the misalignment related to builders constructing heavier roof and floor slabs because they perceive them to be safer in earthquakes, stating, "*That's like one of the misconceptions in an earthquake, that things are safer if they are so heavy that they cannot move, right? … though they can actually break."* In other words, this interviewee is explaining that builders and homeowners often perceive heavier reinforced concrete roofs and floor slabs as safer because they assume that this added weight would prevent the structure from moving in an earthquake, when this added mass may actually increase building damage (Murray et al. 2022).

IMPLICATIONS

This study documents the need for increased research on technical construction capacity-building to support the informal construction sector as they prepare for the different types of hazards they are exposed to. Specifically, this research shows the lack of existing training programs aimed at increasing resilience to Puerto Rico's less frequent yet severe hazard type: earthquakes. Interviewees expressed practical guidance for organizations aiming to communicate technical construction recommendations in Puerto Rico that address misalignments between perceptions and engineering assessments of housing safety. Interviewees also emphasized key aspects of technical training strategies that align with literature on communication, such as the value of demonstrations to show trainees the benefits of changing their behaviors (Dearing 2009). Building from this practical and theoretical guidance, implementing groups and researchers can design capacity-building programs that intervene in misalignment areas amid the changing risk and housing safety perceptions in Puerto Rico's post-earthquake window of opportunity for change (Goldwyn et al. 2021).

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