ENGINEERING DESIGN RECOMMENDATIONS FOR RESILIENT HOUSING: A CASE STUDY OF DAR ES SALAAM IN EAST AFRICA

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Executive Summary

Low-lying and low-income communities situated along the coast of East Africa are susceptible to more frequent flooding events caused by climate change and rising sea-levels. Addressing the physical vulnerabilities of housing in these areas are more critical now due to increasingly unpredictable flooding and the fervent population growth of dense cities, which places more pressure on existing infrastructural systems. Increasing densities of informal settlements in these flood risk zones creates greater physical vulnerability due to less resilient housing construction and inadequate flooding protection. In response to this problem there exist various strategies oriented to improve the physical resilience of housing in these areas, yet there is an observed lack of improvement or effectiveness of solutions.

This research report assesses the barriers preventing effective application of housing solutions for improving flooding resilience for housing within the context of Dar es Salaam, Tanzania, which was selected due to its rapidly increasing population and vulnerability to floods. Five key obstacles that inhibit solution effectiveness are: social vulnerability, improper incremental housing practices, a lack of knowledge and awareness of existing solutions, cultural inhibitions to proposed solutions, and gaps in government housing policy and implementation.

Desk research of academic papers, reports, and publications revealed existing solutions addressing disaster risk reduction and management, disaster response tools and guides, factors contributing to social vulnerability of communities in flood-prone areas, and locally available materials. Interviews with stakeholders from different perspectives (humanitarian response, local and foriegn material research, and non-government organizations) revealed nuances in barriers, highlighting areas where existing solutions fail. A mapping of barrier cause-and-effect factors revealed lack of communication between stakeholders to be a common denominator accentuating barriers to solution effectiveness. The report concludes with a proposed realignment of existing solutions that specifically target communication between stakeholders, identifying four categories of approach types: (1) research and academic, (2) government, (3) non-government organization, and (4) collaborations between multiple stakeholders.

Acknowledgements

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- Dr. Given Justin Mhina, Lecturer at Ardhi University
- Dr. Elinorata Mbuya, Research Fellow at Ardhi University

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Introduction

Because of climate change and rises in sea-level, low-lying communities located along coastal regions in East Africa are more susceptible to floods than before. In addition to rises in sea-level, the increasing unpredictability of cyclones, heavy rainfall, and changes in weather patterns increases the amount of damages resulting from flooding disasters for impacted communities.[1] Cities such as Dar es Salaam are urbanizing rapidly because of an exponential growth in population. This places additional pressures on the unmet demand for affordable housing and results in a large increase in settlements located within informal zones, while also increasing vulnerability to flood risk and housing damage. This report aims to address the lack of housing resilience amongst flood-prone and low income communities within Eastern Africa's coastal zones.

The current research is a continuation of the work started last year with the Resilient Affordable Housing for Flood Risk Reduction: A Review of Interventions in Four Cities in East Africa, which was a partnership between Pennsylvania State University and Engineering for Change to identify resilient engineering design solutions and strategies for resilient housing in flood-prone areas in East African countries. In the 2020 research, technologies, methods, and actions implemented in four critical cities in Africa were studied and documented. This year, the focus of the research is more on finding targeted solutions by identifying the barriers and the strategies to face them. The key findings from the previous report are as follows:

- The systemic issues that frame flood risk among low-income settlements exist at different levels: (1) planning, urban design, and infrastructure and (2) the physical structure of houses.
- Solutions, strategies, and preventive measures that address the physical vulnerability of houses can be categorized into three scales: (1) infrastructure and superstructure of construction, (2) building materials, and (3) urban systems.

This research is the collaborative effort of Pennsylvania State University and Engineering for Change to provide a preliminary foundation for future collaborations through stakeholder engagement co-creation workshops and community engaged-research in Tanzania.

The following goals defined and directed the scope of the investigation:

1. *What are the current building materials, technologies, and strategies that are being implemented to reduce the physical vulnerability of housing in settlements affected by floods in the region?*
2. *What are the barriers and diffusion drivers that can either enhance or discourage the implementation of identified solutions?*
3. *How might we help with the implementation of the identified solutions?*

To do so, we reviewed the existing solutions and scrutinized causes for unsuccessful solution implementation, keeping in mind the ambition of proposing recommendations for resilient housing in flood prone regions in East Africa. The main question driving this research is: "*What are the barriers that discourage the implementation of the identified solutions for the resilient housing in East African flood-prone areas*?". Since the barriers related to these problems are manifold and caused by different issues from various sectors, we narrowed the case study to Dar

[1] Michael Oppenheimer et al. "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities: Supplementary Material." In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, 2019.

es Salaam, Tanzania. In contrast to the other cities that were previously studied, Dar es Salaam is highlighted as a case study of a metropolitan area showing various critical climatic and sociological factors.[2]

Methodology and research strategy

The methodology used for conducting this research included desk research and expert interviews. Concerning desk research, we looked at reports, policy documents, and academic publications both specific to the study area and to similar areas worldwide (e.g. Brazil). In addition, a series of interviews have been conducted to gather expert insights from various stakeholders involved in the improvement of housing in the region. We targeted, in particular, stakeholders from the following sectors: authorities (governments), non-governmental organizations (NGOs), risk management, architecture, and material sciences.

In order to find the barriers related to the solutions for resilient housing, we went through the list of solutions found by our team in the 2020 term. The diagram below shows the classification of these solutions. As shown, the solutions are divided into urban policies, which are related to national and local governments, housing construction, and housing structures. This classification informed our desk research and interviews.

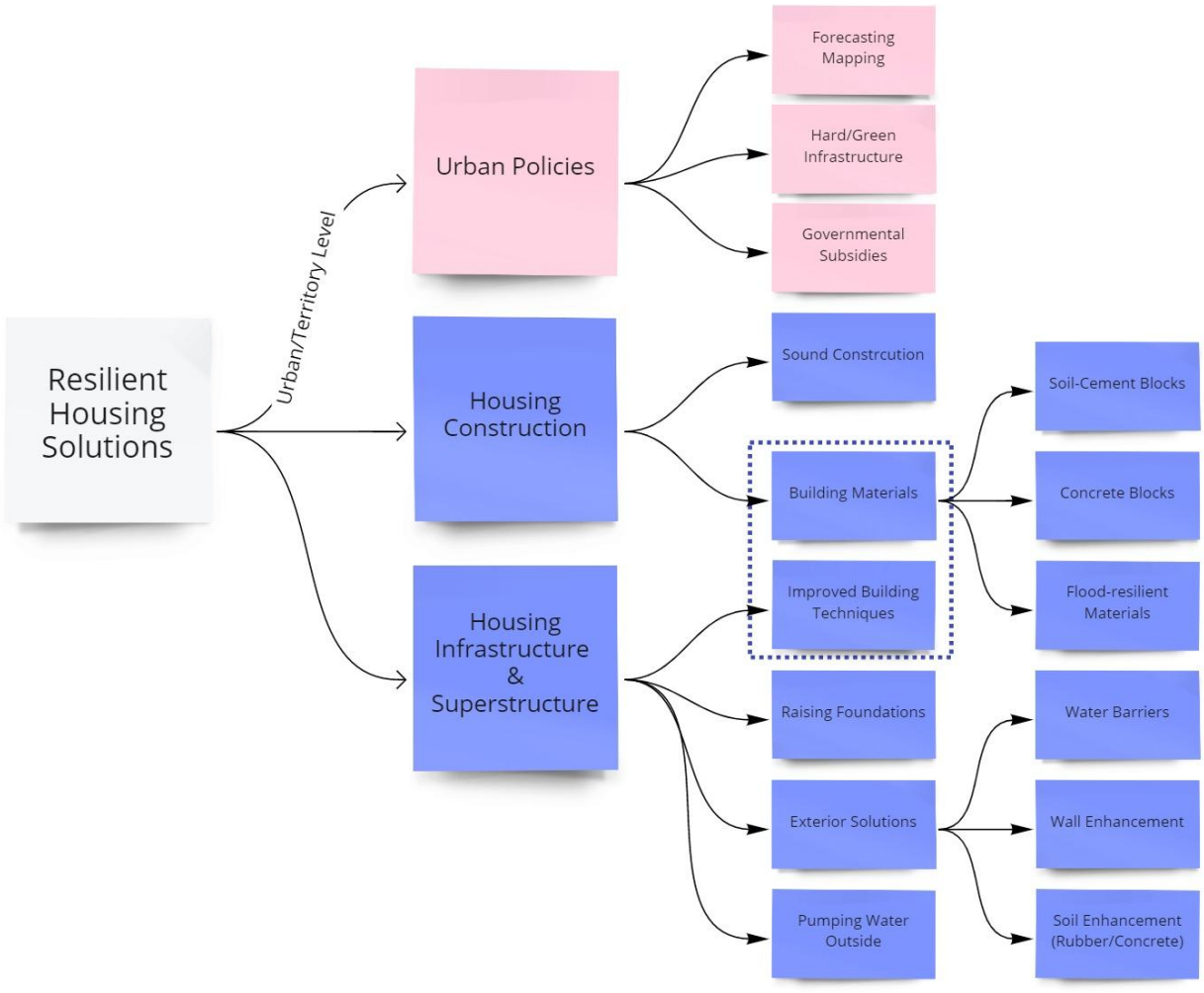

Figure 1. Existing resilient housing solution categories

[2] Elinorata Mbuya, "Vulnerability Analysis of Building Structures to Climate Change: The Case of Flooding in Informal Settlements in Dar es Salaam, Tanzania," PhD diss., (Ardhi University, 2017).

We reached out to those stakeholders using the academic networks provided by our partner and used snowball sampling to reach out to additional and relevant experts by mail. We prepared interview protocols that were tailored to the expertise of the interviewee. Video conferencing tools were used to perform the interviews. The interviews were only recorded with the consent of the participants. For meetings that were not recorded, the team took notes to document the insights gathered. Following these expert interviews, we carried out a qualitative data analysis process to identify themes and claims around the challenges preventing the resilient housing solutions from being implemented. Based on those gained insights, we then developed recommendations to help with the successful implementation of the assessed solutions.

Site Analysis: Dar es Salaam, Tanzania

Located along Africa's eastern coast, Dar es Salaam is the largest city in Tanzania and is the fifth largest city in the continent with a current population of 7 million people,[3] a 0.3 million increase since 2019.[4] The city experiences an average rainfall of 1000 mm and a humid climate, making it a very wet region.[5] Approximately 8% of Dar es Salaam falls under the 10 m contour line[6] and has an increased risk of flooding as a result of climate change and increases in sea-level. In addition, 25% of residents living in Dar es Salaam live in the Msimbazi River Basin, the city's most flood-prone area.[7] According to the Tanzania Urban Resilience Program, approximately 2 million people in Dar es Salaam identified as impacted by flooding, making up about 39% of the city's population. Figure 2 is a photograph of riverbank erosion next to a settlement in Dar es Salaam caused by climate change-related extreme weather events and inadequate riverline maintenance.

Furthermore, the physical infrastructure of Dar es Salaam is susceptible to significant damage due to sea-level rising, flooding, drainage blockages, and wastewater pollution.[8] Due to inadequate supply of housing and rapid urban density growth, Dar es Salaam has many informal settlements, a majority located within the high-risk zones for flooding in Tanzania. Informal settlements in Dar es Salaam lack the strength to endure periodic flooding in the city and about 80% of building structures are constructed within informal settlements.[9] This is made more difficult by financial limitations in constructing, rebuilding, and improving households in informal zones. Informal zones, which are areas where residents do have legal ownership of the land they live on, do not comply with local planning standards; this incompliance increases the physical vulnerability of buildings.

A survey of local housing types in Dar es Salaam reveals typologies ranging from Swahili houses, semi-detached houses, L-shaped houses, H-shaped houses, U-shaped houses, row houses, single story houses, and walk-up apartments; the structure of these houses can be made from vertical and horizontal poles or soil brick walls that

[3] Source: Populationstat, Population in Urban Area, 2021.
[4] According to E4C's Report Resilient Affordable Housing for Flood Risk Reduction, Dar es Salaam had a population of approximately 6.7 million in 2019.
[5] Elinorata Mbuya, "Vulnerability Analysis of Building Structures to Climate Change: The Case of Flooding in Informal Settlements in Dar es Salaam, Tanzania," PhD diss., (Ardhi University, 2017).
[6] Abiy Kebede and Robert Nichools, "Exposure and vulnerability to climate extremes: population and asset exposure to coastal flooding in Dar es Salaam, Tanzania" (*Regional Environmental Change*, 2012), 1.
[7] *Tanzania Urban Resilience Program: Annual Report 2019 (English)*. Washington, D.C.: World Bank Group, 4.
[8] Tabaro Kabanda, "GIS modeling of flooding exposure in Dar es Salaam coastal areas" African Geographical Review (39-2, 2020), 1.
[9] Elinorata Mbuya, "Vulnerability Analysis of Building Structures to Climate Change: The Case of Flooding in Informal Settlements in Dar es Salaam, Tanzania," PhD diss., (Ardhi University, 2017).

are plastered by lime-based cement, cement, or sand paste.[10] Houses in Dar es Salaam are constructed from adobe, sun-dried mud bricks, burnt bricks, stone masonry, and conventional building materials, such as concrete and sand blocks, and concrete block walls.[11]

Figure 2. Riverline erosion along the Mbezi River in Dar es Salaam, Tanzania
(Photo credit: Given Justin Mhina, 2019)

Barriers to implementing solutions for improving housing resilience

As indicated in the 2020 report Resilient Affordable Housing for Flood Risk Reduction: A review of interventions in four cities in East Africa, which listed physical housing and infrastructural solutions for improving housing resilience, there are several approaches for tackling flood risk reduction. Despite the quantity of solutions and strategies addressing housing vulnerability, solutions as summarised in Figure 1 are not effective with regard to building durability, application, and adoption. Affecting the physical strength of built solutions, how occupants use these solutions, and end-user acceptance, the obstacles that restrict these solutions' feasibility and effectiveness according to the data in the scope of this study are listed below:

- A lack of knowledge and awareness of existing solutions
- Cultural inhibitions to proposed solutions
- Gaps in government housing policy and implementation
- Social vulnerability, including poverty and unemployment

[10] According to Mbuya's research, housing is constructed from conventional building materials and earthen materials. The building typology also ranges in form and shape, 125-143.
[11] According to Mbuya's research, an inventory of materials and construction details of housing in Dar es Salaam revealed that more conventional building materials (concrete and sand blocks) were used for the main house structure than adobe materials, 133.

- Improper incremental housing practices

This report will discuss the factors that contribute to these identified barriers in Figure 3 and how these obstacles pose challenges to improving housing resiliency in low-lying coastal zones in Dar es Salaam, Tanzania through desk research and interviews revealing contextual examples and cases outside of Africa.

Figure 3. Barriers impacting solution effectiveness

Desk research and interviews revealed how these barriers are interconnected and share the same causes and effects, as shown in Figure 4. In addition to barriers (social vulnerability, for example) directly impacting other barriers (gaps in government housing policy and implementation), common denominators causing multiple barriers were identified, highlighting opportunities for effective and targeted solution approaches.

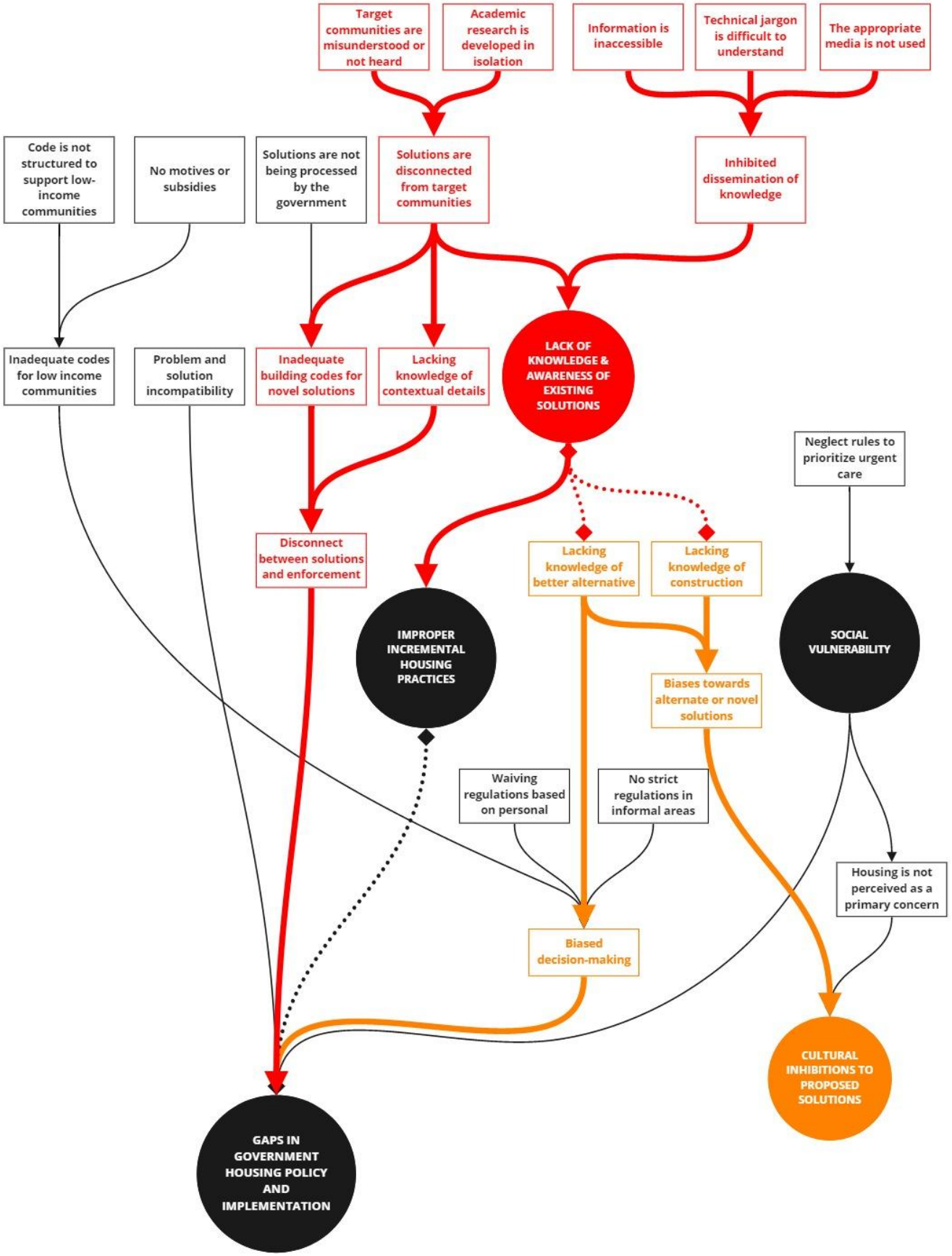

Figure 4. Flow tree of multiplier effect mapped across barriers to improving flooding resilience

Social vulnerability

The first barrier that the solution designers face is related to the social vulnerability of the end users, which is a measure of potential negative impacts caused by external stressors, such as poverty and unemployment. The barriers related to social vulnerability arise from two important factors: (1) the solutions might not be affordable or (2) the solutions might not be accessible for people in the targeted area.

Unaffordable Solutions

In many cases, the most recurring barrier is related to the solutions' unaffordability, especially for solutions related to the construction or reconstruction of houses. One of the interviewees stated that this impacts low-income households and people who are migrating from rural to urban areas or do not have the financial resources to adopt certain solutions. This financial constraint limits the benefits of solutions related to materials and house construction. People prefer to construct their housing by themselves instead of hiring experts or professionals, because it is less expensive for them as stated by an expert in incremental housing.[12] In these scenarios, because they do not have access to some equipment, materials, and the knowledge of how to use them, the people build their houses with weaker materials and improper techniques. In this case, having a well-constructed house is not a priority for people with low income, who prioritize access to food, clean water, and decent work more than housing.[13] Furthermore, some solutions proposed by academic institutions and NGOs may seem more luxurious and fancier than what the people may want, which can cause rejection from the end-users.[14]

Inaccessible Solutions

Alternatively, some of the solutions that are more affordable for people in flood-prone areas are not accessible. This barrier arises from the fact that factories, workshops, and associations that offer these solutions are not located in the same area as the end-users, or the infrastructure is not adapted to deliver the materials or equipment. As an example, we learned in an interview that for some people in Brazil, there is no location in their vicinity offering bamboo for structural use, despite their interest in using bamboo as a structural housing element and their ability to afford it.[15] On the other hand, areas close to material production zones have a great opportunity to offer additional jobs and sources of income for local people. For instance, communities in Dar es Salaam have established local economies in the form of domestic shops, where women make bricks and men sell them to the constructors.[16] This workflow simultaneously enables a great income generation plan for people in low-income settlements as well as produces more sound materials for use in their construction processes.

Improper incremental housing practices

As a result of social vulnerability, people are not able to construct their houses consistently and must build gradually. This process, also called incremental housing construction, can be considered as another barrier for some solutions. As discussed before, some people cannot afford to build their houses. Even with financial aid

[12] Interview with Dr. Jose Pinto Duarte
[13] Interview with anonymous expert
[14] Interview with anonymous bamboo material experts
[15] Interview with anonymous bamboo material experts
[16] Interview with anonymous expert

(e.g. programs like microfinancing) they can only build parts like the kitchen or toilet.[17] This incremental housing leads to different problems that weaken the resiliency of housing in the area.

The first problem that occurs due to this barrier is a flood-prone layout for the houses. This happens due to increased potential empty spaces in the plan of the house, which increases the risk of flood water finding its way to different parts of the structure.[18] Another issue with improper incremental housing practices arises from the different quality of materials and labour that have been used in construction. Sometimes a part of a house is made of higher quality material, while the other parts are weaker. In these scenarios, the weaker part may cause problems for stronger spaces too. Another problem in improper incremental housing practices is the lack of ability to use exterior solutions. When the house is being constructed in different turns, water barriers or exterior wall enhancements cannot be applied because the development of the house and definition of exterior walls is uncertain. For example, the photographs in Figure 5 show collapsed houses along the Mbezi River bank, some with interior walls or foundations now exposed to the elements. As a result, the presence of water protection in the building walls is not clear.

Figure 5. Damaged houses along the eroded Mbezi River bank, examples of incremental housing (Photo credit: Given Justin Mhina, 2019)

[17] Interview with anonymous expert

[18] Elinorata Mbuya, "Vulnerability Analysis of Building Structures to Climate Change: The Case of Flooding in Informal Settlements in Dar es Salaam, Tanzania," PhD diss., (Ardhi University, 2017).

Lack of knowledge and awareness of existing solutions

One barrier that restricts solution effectiveness to the housing problem in Dar es Salaam, Tanzania is the lack of knowledge and awareness of existing solutions, where individuals are not fully aware of existing solutions for improving housing flooding resilience. Interviews with experts in housing policy and material research in Dar es Salaam suggest that this barrier is caused by either an inadequate dissemination of knowledge, misaligned design solutions, or a combination of these factors. Consequently, this barrier can result in a reluctance to accept proposed solutions, further disrupted communication between designer and user, and incorrect application of proposed solutions. The representation in Figure 6 shows the causes and effects of this identified barrier. In the following section, we will explore the identified causes and effects in more depth.

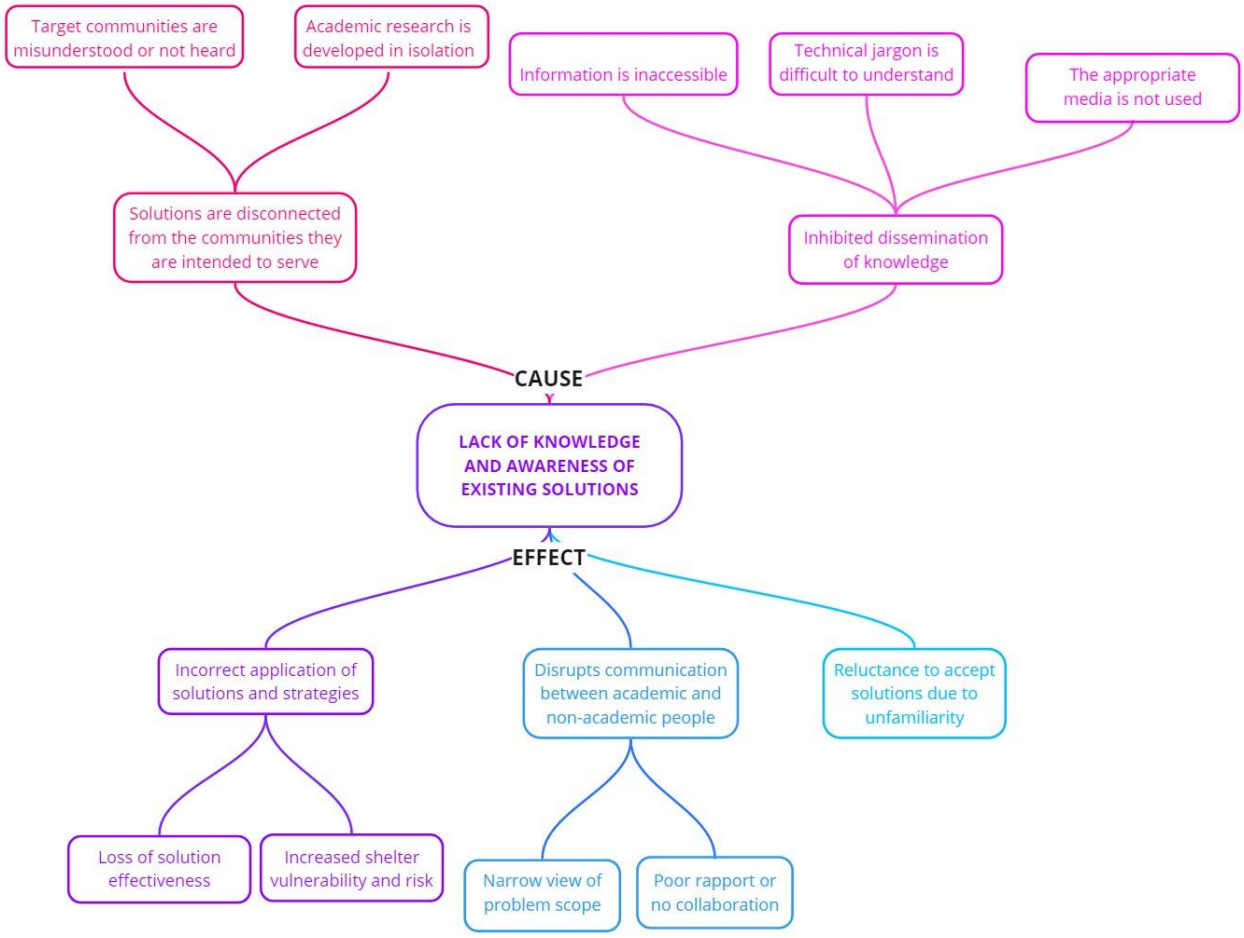

Figure 6. Cause-and-Effect: Lack of knowledge and awareness of existing solutions

Inhibited dissemination of knowledge

Inadequate dissemination of proposed housing solutions among impacted communities can be caused by a number of factors. One factor is inaccessible information. For example, when technical jargon is too difficult to understand, publications of useful research cannot be used by layperson audiences because the language is too difficult to understand. Along the same vein, solutions using difficult technical language cannot be replicated or applied properly. In the case of housing and construction, individuals that cannot read architectural or engineering drawings will be unable to build their homes by themselves and have to rely on a third-party as

highlighted by an expert in incremental housing; occupants who do not understand construction drawings or technical language may receive a product or solution that does not meet their expectations, reflecting an issue of understanding.[19] Furthermore, academic research that is not open-source is difficult for non-academic communities to access outside of research institutions and conferences. As a result, such solutions, even if developed and publicly shared, are not directly shared with target communities.

Inhibited dissemination of knowledge can also be caused by inadequate financial resources or top-level support. For instance, the National Housing Building Research Agency (NHBRA) encountered challenges to share their technology and research at a large scale[20] for workshops, training, physical demonstrations, and outreach programs as stated by experts in earth-based construction technologies in Tanzania.

Solutions are not appropriate for the target communities

When academic research is developed in isolation and without feedback from target communities, the resulting solutions might end up not meeting the commnities' needs. This includes instances where designers assume to know the best solution without keeping the true needs of the user in mind. Solutions that are developed with the wrong target audience (e.g., scientists instead of actual end-users) are examples of disconnected solutions. This disconnect can be caused by a gap in interaction between practical organizations conducting fieldwork and institutions conducting research as mentioned in an interview with a humanitarian-and-disaster response expert.

A house design that is considered a good engineering solution on paper may not be as effective when built in the real world context. As mentioned by the humanitarian-and-disaster response expert, a design that meets engineering criteria but neglects the social and cultural criteria of the end-user can result in occupants feeling uncomfortable or unsafe. In one example, when providing housing relief to a refugee community, the designers did not take into account the community's religious significance in separating men and women in the household. In response to the wide windows incorporated in the shelter design, female users did not feel safe because the proposed solution did not provide enough privacy. In this case, the solution, because it is disconnected from target users, does not truly solve the problem. From an engineering perspective, a good measure of success of strategies or solutions would be whether or not these solutions fixed identified problems as shared by this same expert.

Reluctance to accept solutions

Communities may not be receptive to unconventional material solutions or strategies because they are not aware of the applicable effectiveness. Earth-based technologies and solutions developed by NHBRE, for example, needed to be presented in building demonstrations and visitable on-site prototypes to provide physical proof of material suitability as affordable housing solutions. Many people in Dar es Salaam are not aware of the comparable or improved strength of earth-based technologies over cement brick available in the market, and may opt for the latter solution even if it is not as suitable.[21]

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[19] Interview with an expert on incremental housing

[20] "A Review of the NHBRA Operations on the Development and Promotion of Affordable Housing Products." (University of Warwick, 2014).

[21] Interview with two experts in earth-based construction technologies in Tanzania

Disrupted communication between designer and end-user

Another consequence to this barrier is miscommunication inhibiting future solutions through poor rapport between stakeholders or broken collaborations. Solutions that fail to meet the end-user's expectations can hinder willingness to collaborate due to breaches in trust or rapport. As mentioned earlier, a family that receives a shelter that fails to satisfy their desire for security may not be as receptive to future solutions to improve their home.

When communication is disrupted between stakeholders, collaborations can be inhibited by a narrow view of the problem scope as involved parties are approaching the problem separately and ineffectively. For example, when developing a risk reduction model, it is important to consider not only the engineer's perspective, but the work experts and practitioners are conducting in other fields as stated by a risk reduction framework expert. In an interview, they noted that to gain a broader perspective in framework design, the local (impacted) people's voices need to be heard as well, as their priorities and perceived risks are different.

Incorrect application of solutions and strategies

If end users do not possess adequate knowledge or awareness of received solutions, it can cause increased shelter vulnerability and risk of flooding damage. When a building is maintained improperly, or when a strategy is not applied correctly to a problem, the solution loses its effectiveness. As hinted previously, this is caused by a lack of adequate communication between end-user and designer, which can be verbal or visual (instructions and construction drawings). Further, overreliance on 'rules of thumb,' which are informal procedures that do not get reviewed regularly, means that required maintenance due to changes in environmental exposures may be neglected.

Gaps in government housing policy and implementation

Another challenge that impedes the implementation of some solutions in the resilient housing problem is the inadequacy of building codes and standards. There are several solutions related to materials and techniques of constructing more resilient houses that are neglected because their implementation requires a set of regulations. This issue causes a reluctance and bias among constructors and homeowners to implement the solutions because people do not want to experience further problems after building their houses. These problems include safety issues for inhabitants, monetary fines from authorities, and demolishing their houses. Coupled with these gaps, there are times that compliance with the building codes are inadequate. As shown in Figure 7, these issues come from biased decision making, disconnected solutions from the enforcement teams and sometimes, the social vulnerability of the communities.

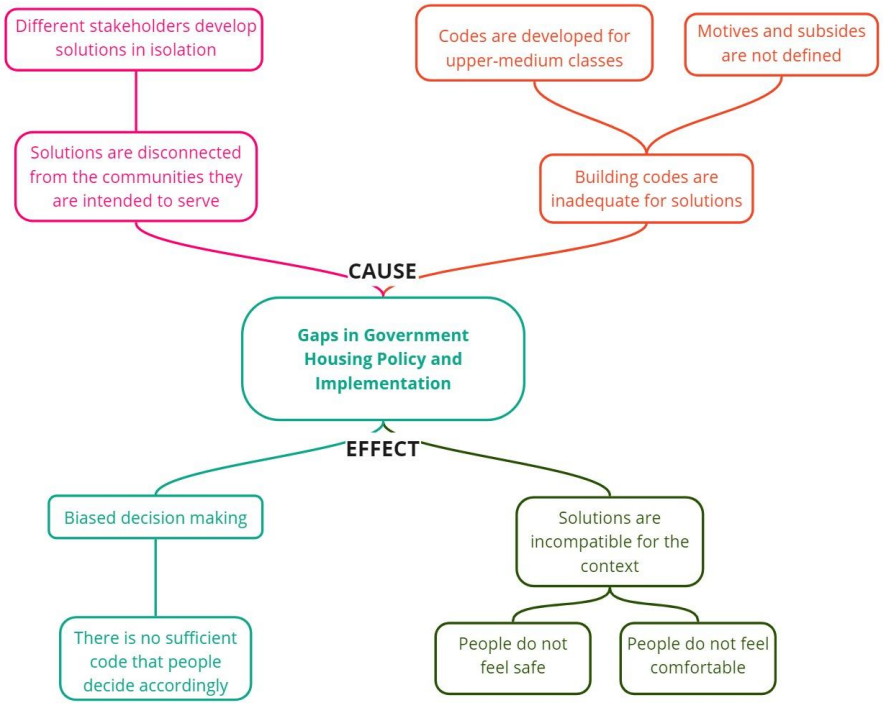

Figure 7. Cause-and-Effect: Government Housing Policy Gaps

Inadequate codes for low-income communities

Sometimes the codes and regulations are structured in a way that can be abided only by people in the upper, middle, and high income classes of the community. In an interview, we learned that programs suggested in the building codes are not well-structured to support low-income communities and there are no motives or subsidies to help people from lower-levels of the community to abide as highlighted by one of our interviewees.[22]

Disconnect between the solutions and the community

The problem with some of the solutions related to the resilient housing problem in flood prone areas is the disconnect between stakeholders proposing these solutions and the community who are supposed to benefit from those solutions. Solutions that are developed by non-governmental organizations or academic institutions but are not checked for government or policy compliance cannot be implemented on large scales because they may not follow housing codes and regulations.[23] In some cases, a novel technique or material in a particular context is disconnected from the end-users because it has different purposes and the framework for using it in the building industry is not ready.[24] However, as the solutions developed by humanitarian non-governmental organizations are supposed to serve the minimum standards, it might be hard to abide by.[25] Another solution for this problem is to study the codes related to the same technique or material in other countries. For example, for utilizing bamboo structures in Brazil, the scholars started studying the building codes related to this material used in China.[26]

[22] Interview with an anonymous expert
[23] Interview with two experts in earth-based construction technologies in Tanzania
[24] Interview with anonymous bamboo material experts
[25] Interview with a humanitarian-and-disaster response expert
[26] Interview with anonymous bamboo material experts

There are failed cases of implementing novel solutions in the housing and sheltering contexts when the persons in charge of supervising the implementation were not fully aware of the novel framework, which is interrelated with lacking knowledge and inadequate building codes. In an example of a re-sheltering project shared in an interview, when authorities started taking land rights from the local people without knowing the details of the sheltering program, local communities were pushed to rebuild their shelters in lands that they did not own, creating additional challenges of land ownership.[27]

Compatibility issue

This barrier manifests as incompatibility between the problem and the proposed solutions. Many solutions that are using novel systems (e.g., solutions from outside the community) can be neglected from the perspective of the authorities and constructors, as there is not a standard source, handbook, or rulebook for them to abide by. To add, monetary support like subsidies might not be accessible for people who are using these solutions, as the framework is not defined.[28]

From another perspective, when local people cannot find a building code about the methods of using a solution, they might not feel comfortable using that in their houses. In an interview with bamboo material experts, we learned of an example in Brazil where the local people did not accept bamboo as an alternative building material because they could not find any proper references for building with bamboo and believed it to be inadequate for their house structures.[29]

Biased decision-making based on incomplete or inaccurate information

The individuals responsible for regulating construction in different sectors and industries may or may not live among impacted communities, which can result in various forms of bias. First, these supervisors may not be entirely familiar with the logistics of the novel solutions, and they might prefer more familiar methods, even those that have led to their current situations. Second, they may have historically received waivers on some of the regulations for prior projects based on their relations with policy-makers. This connivance might cause several problems for the people living in the housing units constructed by them. Finally, whenever there are subsidies involved, a mechanism is needed to check if the allocation of the money to the people is compliant with the regulations or not.[30] This is intensified in slum areas that lack robust mechanisms for ensuring compliance with existing regulations. In some cases, the enforcement agents may also waive parts of the codes to accommodate ill-informed cost cutting measures. They try to ignore some strict rules to make it possible for low-income people to find a shelter for their families, but over time, these neglections cumulatively cause chaos in construction.[31]

Cultural inhibitions to proposed solutions

Another barrier that restricts solution effectiveness to the housing problem is cultural inhibitions to proposed solutions, and refers to moments where individuals are reluctant or resistant to solutions that do not align with their expectations, lifestyle, or culture. As represented in Figure 8, this barrier is caused by biases towards

[27] Interview with a humanitarian-and-disaster response expert
[28] Interview with an anonymous expert
[29] Interview with anonymous bamboo material experts
[30] Interview with an anonymous expert
[31] Interview with an anonymous expert

alternate material or technology solutions or, like the lack of knowledge or awareness barrier, misaligned design solutions. Consequently, this barrier can cause a reluctance to accept proposed solutions, contextually unacceptable solutions, or housing not being perceived as a primary concern among impacted communities.

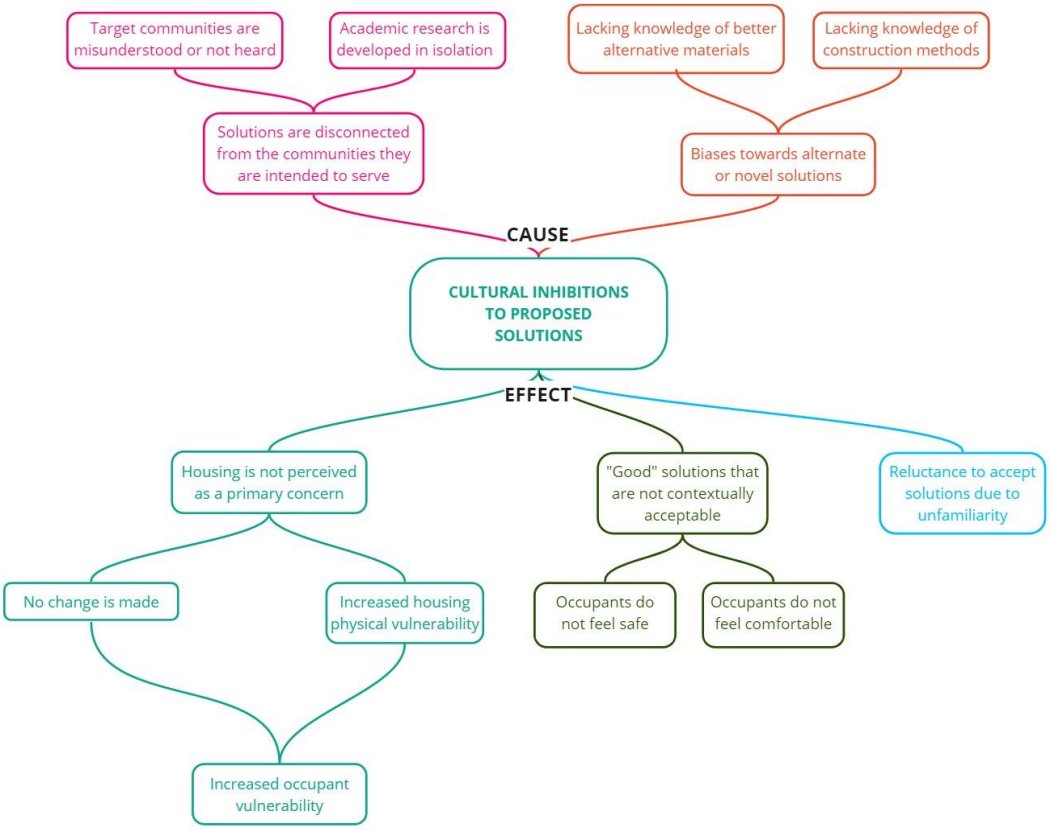

Figure 8. Cause-and-Effect: Cultural inhibitions to proposed solutions

To illustrate this barrier is an anecdote describing the engineered design approach to helping internally displaced persons (IDPs) in eastern Ukraine following the conflict in 2014. The anecdote describes humanitarian efforts to reshelter displaced people in Ukraine and the post-occupancy evaluation once the construction of new shelters were complete:

> *The minimum standard [for floor area] is 17-and-a-half meters squared for a shelter in Ukraine. When the conflict was happening in eastern Ukraine, people were being displaced to move to new places. [Because] they actually had quite a lot of land to build shelters, [the response was to] build them at larger than the minimum standards that were available. Then they found that, again, the people didn't feel safe in large, empty spaces. They wanted to be closer together [and have] a sense of community. People having that kind of close connection meant that two or three families were staying in the same shelter, even though they have separate shelters available for them. [As a result], it was additional work that wasn't necessary and could have quite easily been fixed if [the designers] had spoken to the people and asked what they wanted.*
>
> *-provided by a humanitarian-and-disaster response expert*

In this case, the target community was provided a solution that was not compatible with their local customs and culture. Because the people were accustomed to intimate communal relationships, they did not feel secure in larger spaced homes and, as a result, left many unused shelters. As represented in Figure 9, the solution did not adequately address the needs of the end-users in a number of ways. First, the rationale for increasing the shelter footprint was focused on optimizing the available space rather than considering the local culture of the displaced persons. In doing so, the target community was given new shelters that failed to provide comfort and security, ultimately contributing to unused shelters and wasted resources.

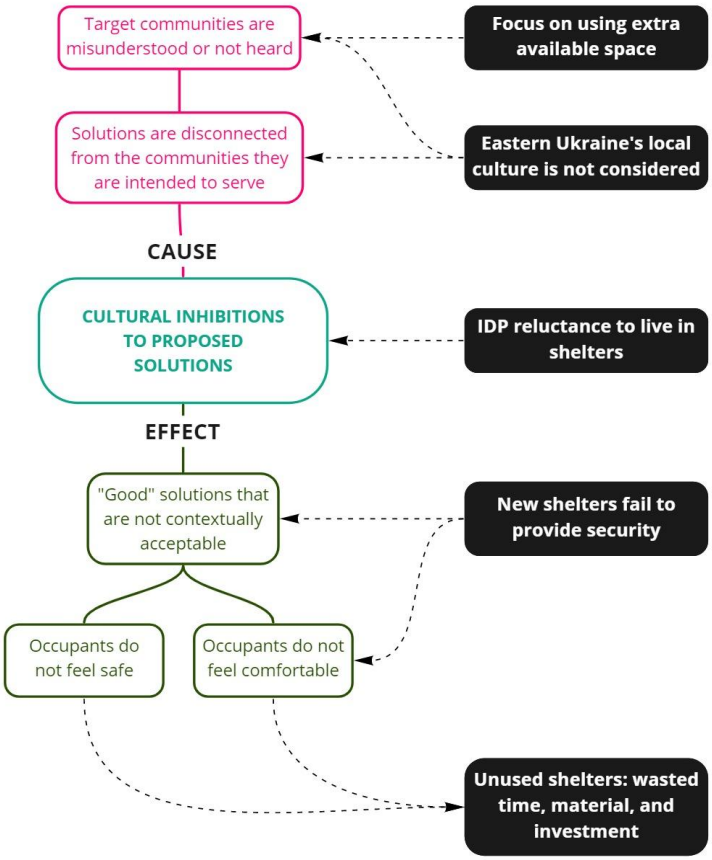

Figure 9. Ukraine IDP resheltering case mapped to Cultural Inhibitions barrier

Biases towards alternate or novel solutions

Biases towards alternate solutions and strategies can be caused by a lack of knowledge or expertise in construction methods. If one considers the case of introducing bamboo use in Brazil from a South-South cooperative perspective, integrating a novel material, such as bamboo, requires experimental adaptation into the building design, something that requires a certain level of construction expertise.[32] Similarly, biases towards alternative solutions are impacted by lacking knowledge or expertise in alternative materials. Alternative materials that are proven to be effective in one context may not necessarily be as easily applied in another part of the world because of differences in local building techniques and climate conditions.[33] In addition to different materials, there are also different building methods that vary depending on local traditions, culture, and techniques.[34] Furthermore, an unconventional material or method will not have as much research or

[32] Interview with anonymous bamboo material experts
[33] Interview with humanitarian-and-disaster response expert
[34] Interview with a humanitarian-and-disaster response expert

development as conventional solutions. As a result, unless people are physically shown how a solution performs or relevant building standards are adopted, alternate materials or building methods may not be easily accepted.[35]

Housing is not perceived as a primary concern

Furthermore, when experts do not clearly identify the real needs of target communities before coming up with a solution and do not prioritize them in the same hierarchy, the end users will not be able to adopt solutions not addressing their most perceived urgent needs. For example, impacted communities at a higher risk of cholera and malaria may not be as concerned with reducing disaster risk through improved housing resilience, as explained by a humanitarian response expert.

Cultural inhibitions to proposed solutions can be influenced by financial limitations and other concerns, which can cause housing to not be perceived as an immediate or urgent problem. For example, while conducting research for the 2018 Tanzania Baseline Survey Report on Assessment of Land Rights, it appeared that housing was not perceived as the primary concern for those living within poor communities. Despite living in grass huts with compromised safety, occupants did not consider housing resilience a priority. An interview with an NGO practitioner revealed that the people valued access to the market a higher concern instead; in low income communities, the largest valued problem is not housing, but income generation.

In addition to livelihood concerns, some communities can be more concerned with maintaining health and preventing diseases. For instance, instead of housing, people may be more concerned with access to clean drinking water and how to prevent diseases, such as cholera or malaria.[36] This is especially the case for individuals living in temporary settlements, where long-term residence is not necessarily guaranteed. Another element to consider is the fact that resilience, disaster risk reduction, and housing may not be on the forefront of people's minds because there has not been a need to worry about these issues before. However, due to climate change, cyclones and other natural disasters impacting flooding risk is becoming a more emerging, yet new, issue for low income communities in coastal zones, as noted in an interview with a humanitarian response expert.

Overlap between lack of knowledge and cultural inhibitions to proposed solutions

The overlap between this barrier and lack of knowledge and awareness of existing solutions are indicated in Figure 10. Both of these barriers can be caused by solutions that are disconnected from the communities that they are intended to serve.

[35] Interview with two experts in earth-based construction technologies in Tanzania
[36] Interview with a humanitarian-and-disaster response expert

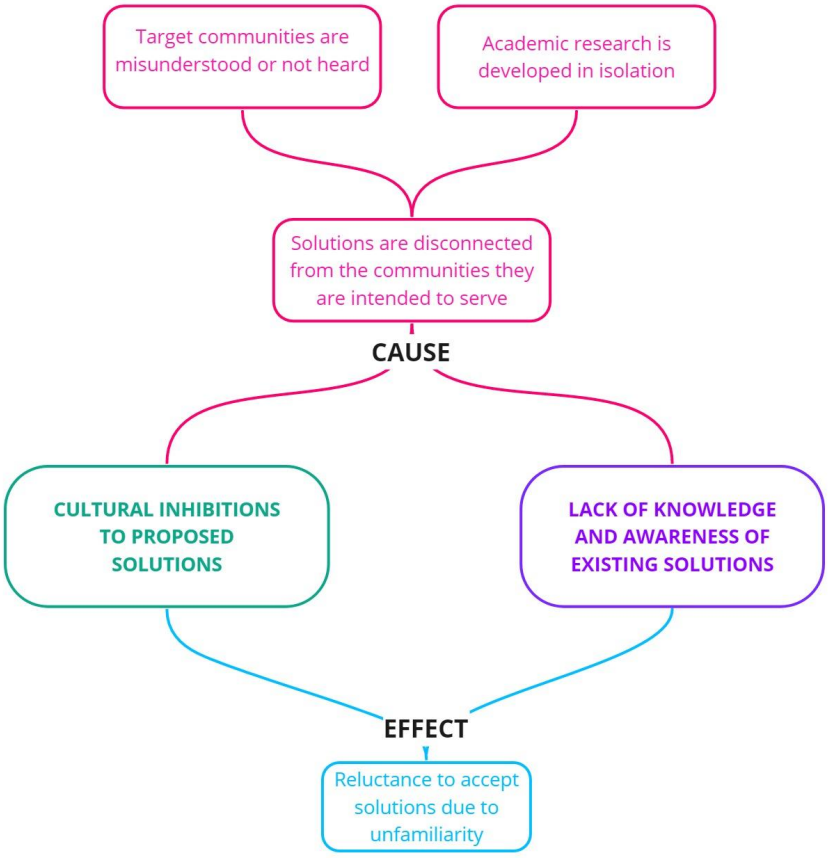

Figure 10. Connection between lack of knowledge and cultural inhibitions of solutions

Applicable solutions addressing identified barriers

This report does not provide new and novel design solutions for improving housing resilience to flooding. Instead, it offers a realignment of existing solutions to the barriers now identified in the research. Following extensive research of existing resources (e.g., publications and expert interviews) regarding disaster risk reduction (DRR) models, novel architectural methods, and outreach programs, we recognized a common denominator that connected a majority of the barriers identified in the report. As illustrated in Figure 11, barriers to housing solution effectiveness are impacted by miscommunication between stakeholders or inadequate awareness about solutions. The barriers identified in the research are represented in circle shapes that build upon smaller, commonly shared factors. Miscommunication between stakeholders reflects a misalignment of goals and results, which contributes to the barriers; inadequate knowledge of research, solutions, and end-users not only contributes to stakeholder miscommunication, but it also hinders effective application of resilience strategies for this problem. Once aware about this common denominator, we can create new solutions and realign existing strategies to potentially address multiple barriers simultaneously for targeted improvement.

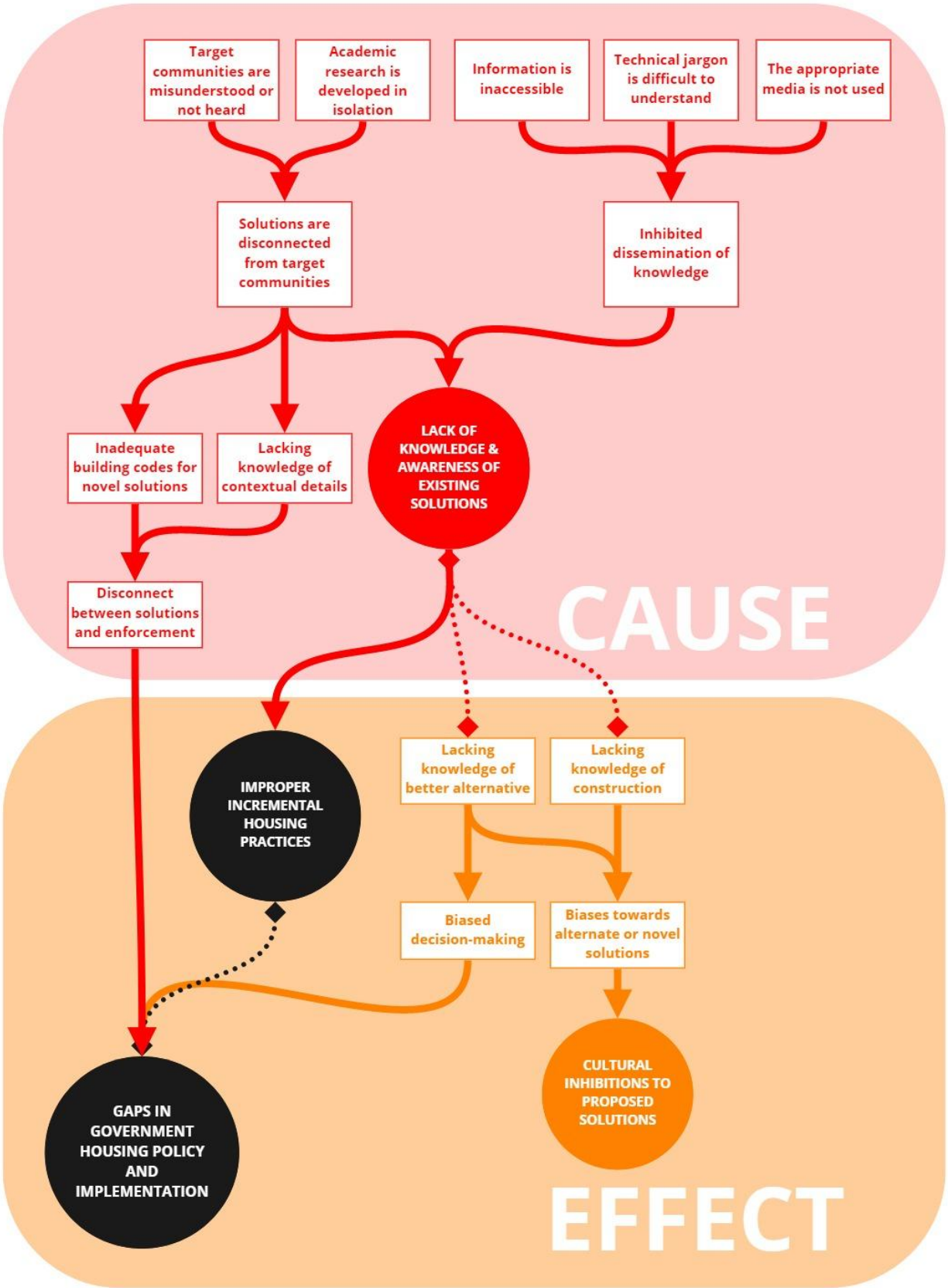

Figure 11. Trickle-down effect of lacking knowledge on identified barriers

A summation of existing solutions can be categorized into three primary types: Research and Academic, NGO, and Government, as shown in Figure 12. As illustrated in the figure, there are three stakeholder types that have differing approaches to improving housing resilience. Opportunities for mix-sector approaches or solutions that require the cooperation between multiple stakeholder types are indicated in the diagrammatic overlap. For example, solution dissemination programs may require top-down government support in addition to the creation and design of the solution intended to be disseminated. Solutions categorized in dual-type approaches (NGO-and-Research and Government-and-Research) can be mentioned in either relevant category, depending on the organization implementing the solution.

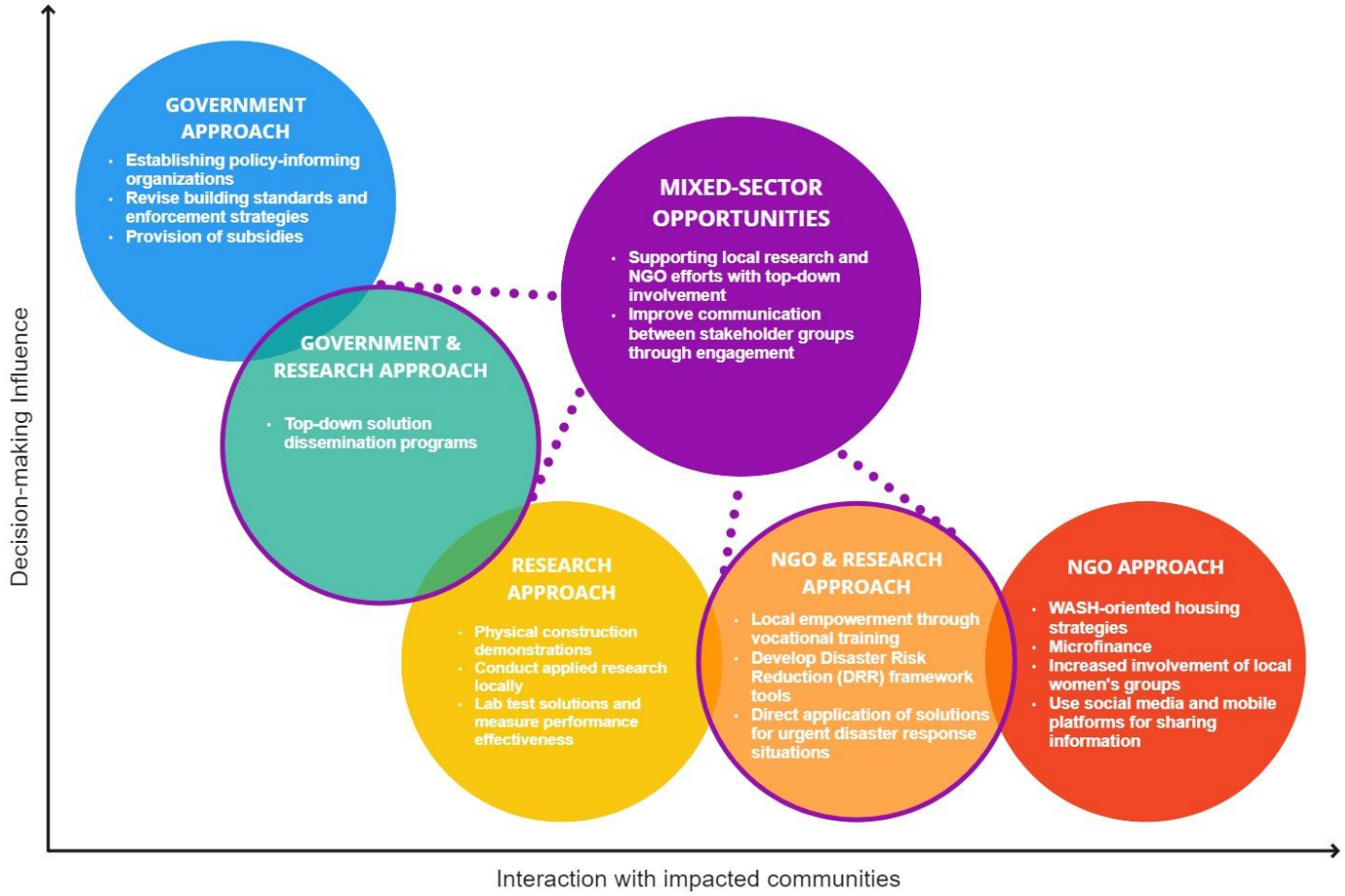

Figure 12. Solution map of Research, NGO, and Government Institutions

Research solutions and approach

Solutions within this category include physical construction demonstrations, locally applied research, material studies, and guidelines conducted by an academic institution or research organization. Physical construction demonstrations are workshops or presentations where housing solutions are built in real-time to the public and are a way to communicate a solution's applicability, building instruction, or performance for end-users. Similarly, this includes community engagement of developed solutions or the application of new technologies in local contexts. For example, in an interview with earth-based construction experts, their organization's approach in knowledge dissemination was to demonstrate to local communities how to manufacture, operate, and build with machine-pressed earth blocks. Their strategy included educating non-experts on the structural potential of earth-based materials and simultaneously empowering them with the skill and knowledge of how to replicate

these solutions. Furthermore, when implementing a novel solution, a series of publically available training sessions and a developed list of targeted standards can be used by builders and designers to match local building codes.[37]

In addition to physical demonstrations and local testing, research-type solutions also include guidelines and tailored suggestions that arise from extensive research. These guidelines offer suggestions for specific levels of expertise, purpose, or professional discipline. One example of a research-born guideline is the *Code of practice for property flood resilience*, which is a set of standards for delivering flood resilience to properties at risk of flood damage in terms of floodwater management, damage mitigation, and recovery. Prepared by CIRIA, a construction industry research organization, the guide includes procedures and requirements for assessing on-site hazards, preventative measures, and property maintenance. Intended users include property owners, engineers, architects, and local authority planners.[38] Another example is the *Scenario Best Practices: Developing Scenarios for Disaster Risk Reduction*, provided by the Cambridge Centre for Risk Studies and the Lighthill Risk Network. The guide provides a framework for the disaster risk reduction (DRR) community to practically apply scenario development for disaster preparedness, response, mitigation, and recovery. The aim of the guide is to equip practitioners with the foundational knowledge of designing and putting into practice their own DRR scenario projections.[39]

Non-governmental organization approach

Non-governmental organization approaches to improving flooding resilience include solutions that engage local impacted communities and respect their local customs in addition to informational materials for experts. Because NGOs have greater interaction with local communities than research institutions and government organizations (as reflected in Figure 12), their strategies are more direct and more effective from a communication standpoint. Furthermore, because NGOs vary by purpose (emergency disaster relief, local organizations, faith-based groups, etc.), they have more varied solutions than research organizations' technologies or government-based strategies.

One such solution is the integration of WASH ideas with housing resilience and shelter improvement. One example is of a WASH-focused approach conducted by an NGO in Tanzania which uses a strategy to introduce the housing problem to locals through health and sanitation. Through an interview with an NGO facilitator in Tanzania, we were told that some people will be more receptive to improving sanitation quality and protecting their well-being than improving their houses. Therefore, this NGO decided to introduce housing through sanitation practices, which were shared through social media; because local community members use mobile devices and social media for managing their businesses and receive large quantities of information in a short time, communicating through similar channels was very effective.[40]

Another direct NGO approach is the assignment of non-governmental aid to help low-income families living in physically vulnerable houses, which addresses local factors of social vulnerability. For example, a microfinance system has been implemented by organizations such as Habitat for Humanity in Tanzania, which aims to help people build more budgets to construct and improve their housing. Through loans and accessible financial

[37] Interview with a humanitarian-and-disaster response expert
[38] David Kelly, Matt Marker, Jessica Lamond, Steve McKeown and Eleanor Blundell, *Code of practice for property flood resilience* (London: CIRIA, 2019), 1.
[39] Strong, K., Carpenter, O., and Ralph, D, *Scenario Best Practices: Developing Scenarios for Disaster Risk Reduction* (Cambridge: Cambridge Centre for Risk Studies, 2020), 8.
[40] Interview with an anonymous expert with experience in NGOs

support, microfinancing strategies help people to develop their houses in areas such as their kitchens, toilets, and other parts.[41]

Solutions in the NGO-approach group also include training guides, response tools, and ground-level support systems. One example of a training guide is the "Building Material Selection and Use - An Environmental Guide", which was formulated by WWF Nepal to provide a disaster reconstruction framework for engineers, architects, project managers, and technicians.[42] The guide provides a disaster reconstruction framework that includes a building material database for relevant regions in Nepal; it is aimed at providing instruction in selecting, procuring, and using sustainable materials for disaster reconstruction. Another instructional manual is the "VCA Training Guide, Classroom Training and Learning-by-Doing," a guide written by the International Federation of Red Cross and Red Crescent (IFRC) Societies. Part of a four-part series in Vulnerability Capability Assessment (VCA), the guide is intended to provide facilitators (NGOs, disaster response organizations, volunteers) with instructions on how to train others to use VCA in their disaster recovery assessments. The IFRC also provides supplemental tools and documents that are aimed to equip readers with the materials needed to conduct risk assessment research and evaluate disaster response.

Government approach

Government approaches to improving housing resilience include broader and wider-reaching strategies intended to impact as many people as possible. Governments have greater influence in policy-level decisions, but have the least direct interaction with local communities. Instead, government-established organizations and institutions that have more interaction with the public provide governments with data to inform policies and regulations.

A few government-established agencies, for example, include the National Housing Corporation (NHC), the Geological Survey of Tanzania (GST), and the National Environment Management Council. The National Housing Corporation was established by the government to reduce the housing shortage in the country. In addition to constructing new houses, the NHC also provides loans for affordable housing. In a 2021 article, the NHC also started to develop their own building materials, which will potentially further lower the cost of housing for end users.[43] The Geological Survey of Tanzania was established to provide geo-scientific data and mapping to the government and other organizations, which is used for locating and assessing areas at risk of climatic disasters. Another government-mandated institution, the National Environment Management Council (NEMC), researches and reviews environmental issues such as pollution, impact assessments, and information dissemination. Following its formation, the NEMC has been developing environmental training to increase the number of environmental experts, managers, and planners in the country; the NEMC also developed a training manual aimed to educate future resilience practitioners.[44]

In 2016, the Tanzanian government, in collaboration with the World Bank Group and the UK DFID, formed the Tanzania Urban Resilience Program (TURP) to address flooding and urban challenges in the country. In 2019, the Tanzanian government also initiated the Msimbazi Opportunity Plan, to directly address the flood risk in the Msimbazi Valley, which is located within Dar es Salaam. The plan proposes to redesign strategies to mitigate

[41] Interview with an anonymous expert with experience in NGOs
[42] "Building Material Selection and Use - An Environmental Guide" WWF Nepal, Hariyo Ban Program, (Nepal, 2016), 1.
[43] Josephine Christopher, "National Housing to cut house prices by producing own inputs." *The Citizen*, (Dar es Salaam, May 2021).
[44] Godwin A. Lena, "Practitioners Novice: Advancing Early Career Environmental Expert Curricula." For *IAIA Conference* (Dar es Salaam, 2021).

flooding hazards, protect infrastructure and people from flooding hazards, and transform existing neighborhoods for resilience.[45] Completed in 2019, the Msimbazi Opportunity Plan organized a Charrette process that resulted in multi-level and cross-disciplinary participation in designing ecological interventions for improving resilience in the Msimbazi Basin.[46]

Another government approach is to support local research and non-government stakeholders with their dissemination efforts. In an example provided by bamboo experts, when trying to educate the public about the effectiveness of bamboo in Brazil, the local government supported their research by allowing them to grow bamboo on certain properties, which provided space to experiment and treat bamboo building technologies.

Mixed-sector solution approach

In addition to these approaches are solutions that are created collaboratively between different categories. One example of an academic-and-NGO solution that addresses miscommunication is a humanitarian demonstration shelter manufactured and constructed by the Building Research Establishment (BRE) in 2017. A collaboration between the Catholic Relief Services and the Building Research Establishment, the shelter prototype was constructed as part of an exhibit to demonstrate how to build a resilient building shelter. Within the shelter were information boards that shared information related to NGO responses to natural disasters. The shelter was created in application of Quantifying Sustainability in the Aftermath of Natural Disasters (QSAND) principles.[47]

Multi-sector strategies also have the opportunity to build upon existing research in different sectors. In 2020, faith-based organizations Catholic Relief Services and KMSS released a report on a capacity building workshop they conducted in Myanmar, with a focus on shelter and settlement construction. The project is a case study of the QSAND tool applied for a programme addressing displacement in Myanmar. The QSAND tool, developed by the IFRC and BRE Global Limited, is a manual that provides instruction frameworks for application in post disaster events, such as geophysical, hydrological, and meteorological natural disasters.[48] In the Myanmar project, the QSAND tool served as a benchmark for sustainability principles, impacting considerations for shelter, community governance, settlement, materials and waste, and social cohesion and integration with the local community, among other factors.

To add, another tool is SHERPA, a self-evaluation tool that addresses sustainable development from the aspect of housing, local capacity building, and process-driven foci. Designed by UN-Habitat, the Valtion Teknillinen Tutkimuskeskus (VTT and also known as the Technical Research Centre of Finland), and others, the tool is intended to be used to consider housing at four primary scales: project processes, territory, neighbourhood, and household. This tool, which can be used for housing design in the Global South, is an approach to sustainable housing with accessibility in mind and is available as an open-source material and on virtual applications. In 2007, SHERPA was tested and used[49] for the UN-HABITAT and Kenya Slum Upgrading Programme (KENSUP); in

[45] *The Msimbazi Opportunity: Transforming the Msimbazi Basin into a Beacon of Urban Resilience: Executive Summary (English)*. (Washington, D.C., 2019).
[46] "The Msimbazi Opportunity Plan: Transforming the Msimbazi Basin into a Beacon of Urban Resilience , Executive Summary." (Dar es Salaam, 2019), 5.
[47] Interview with a humanitarian and disaster response expert.
[48] "Quantifying Sustainability in the Aftermath of Natural Disasters," BRE Global Limited, (2014), 3.
[49] Source: One Planet Network and the Global SCP Projects Database

the project, participants could accomplish integration of community planning of improving basic infrastructure, housing, and environment within the inception process.[50]

Another example of a mixed sector approach is a 2016 report of recommendations for repairing flood-damaged buildings, prepared by the Department for Environment Food & Rural Affairs in the UK. Derived from the collective work of engaged stakeholders from different sectors (charity, businesses, and flood recovery-focused industries), the report shares different frameworks for engaging stakeholders in different contexts. In including a wider range of stakeholders, the report aims to increase overall flooding preparedness among residents at risk. It includes strategies for local skill development and improving information dissemination via a designed web portal for sharing solutions.[51]

Lastly, in 2021, InterAction recently published the "Roadmap for Research: A Collaborative Research Framework for Humanitarian Shelter and Settlements Assistance", a report that focuses on issues related to humanitarian assistance and response and addresses them with a perspective on shelters and settlements. The report provides an overview of the 2021 scope of humanitarian-focused study, spanning a wide range of subjects from disabilities to environmental health. The publication was the joint effort of multiple collaborators like professors in disaster resilience, the National Disaster Management Office, BRE Trust, the Institute for Cooperation and Basic Habitability, and other disaster recovery research institutions. Although recent in its publication, the peer-reviewed report includes guidelines and considerations for situations ranging from including persons with disabilities in recovery to self-help shelter repair in conflict zones. In particular, the report's chapter on "Addressing Disaster Risk in Informal Settlements" notes a gap in existing research on improving housing for informal settlements with regards to flooding; community-based research is suggested as a preliminary approach for more comprehensive research on the topic.[52]

Discussion of opportunities for change and Conclusion

The main goal of this report was to unveil barriers to implementing the solutions identified for resilient housing in East African countries' flood-prone areas and to identify targeted solutions to bypass these barriers. The research team studied the literature and conducted interviews with experts in various related sectors.

The main barriers to the solutions are related to the dissemination of knowledge, either for the governmental authorities, non-governmental organizations, or the people as the end-users of the proposed solutions. The gaps between the experts working on developing solutions and the people living in the targeted areas result in a multitude of barriers. Overall, we found that the solutions are either unaffordable or inaccessible for many end-users, and that proper methods of dissemination of the knowledge to end-users is not used. Many of the solutions are developed in isolated academic environments, and the cost and accessibility for vulnerable people have not been taken into account. Even for the more affordable solutions, the outreach process does not work well. While social media and easy-to-read documents are more interesting for the targeted communities, it appears that the solutions are, on the contrary, in non-user-friendly platforms and full of technical jargon. This disconnect causes a lack of cultural consistency between the solutions and the community.

[50] Source: UN-HABITAT and the Kenya Slum Upgrading Programme report publication
[51] Peter Bonfield, "The Property Flood Resilience Action Plan: An action plan to enable better uptake of resilience measures for properties at high flood risk." (United Kingdom, 2016), 11.
[52] Source: Interaction 2021 Research Roadmap

A next step following this research will be looking for appropriate solutions and strategies to fill these gaps. The initial step might be feasible by making the information easier to use for targeted people. Making use of some communication channels accessible for people and easy to read for non-technical people helps spread out the solutions and avoid the disconnection between people and solutions. Social media, from television networks and radio channels that are more public to Facebook, Instagram, and Twitter which are more specific, can cover a wide range of people to get familiarized with the solutions, especially the novel techniques and materials.[53] After giving them the initial information, the following step is to make the connection more substantial and the familiarity deeper. In this step, holding exhibitions to show the applicability and workability of the solutions[54] and workshops to teach people how to use them[55] can help substantially.

From another perspective, the disconnection between communities and the authority/academia/industry working on their problems requires further investigation and consideration. People in these areas need to be heard to enable conveying the correct issues and needs to the authorities, scholars, and industry leaders. In this sense, social media can again play a major role for raising awareness and collecting the real user needs.[56] Another measure of starting such a conversation is holding community forums and stakeholder workshops.[57] These exchanges can lead to understanding the exact needs of people affected by floods in low-income settlements, so the focus of such events may have a significant impact.

While at first glance financial support and subsidies might be used as a quick solution, it will be more efficient after identifying the exact problems and informing people about the different solutions from which they can benefit. Authorities can then provide financial support and subsidies to the community and ensure that the support is being used appropriately by monitoring and evaluating those programs.

To conclude, the main challenges in solving the problem of resilient housing in these settlements in the region can be summarized in proper dissemination of the knowledge, mutual conversation between authorities and the end-users, and designing and building houses accordingly.

[53] Interview with an anonymous expert
[54] Interview with a humanitarian-and-disaster response expert
[55] Interview with two experts in earth-based construction technologies in Tanzania
[56] Interview with an anonymous expert
[57] Interview with two experts in earth-based construction technologies in Tanzania

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