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Narratives of Caribbean housing flows: step-by-step development and changes in self-organized homes in St. Martin

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Abstract

Purpose – The global housing shortage, intensified by climate change, poses unique challenges for low-income populations, particularly in regions highly vulnerable to environmental hazards, such as the Caribbean. This study investigates housing in Saint Martin, where communities face severe housing shortages and increased exposure to climate-related threats, such as Hurricane Irma in 2017. With limited external support, many residents have adopted self-building strategies, constructing and incrementally modifying their homes to withstand local environmental risks and accommodate changing needs.

Design/methodology/approach – This research, conducted through ethnographic observations and semi-structured interviews with 30 residents, explores how low- and middle-income households built and adapted

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their homes over time, focusing on the construction process, materials, forms and aspects of safety, comfort and beauty. It follows the narratives of six housing units that exemplify a proposed housing typology and documents residents' efforts to enhance durability, functionality and aesthetics under challenging circumstances.
Findings – The findings highlight that self-organized housing practices in Saint Martin are shaped by financial constraints, climate risks and evolving household needs. Residents use incremental construction, climate-responsive design elements, materials perceived as durable and community-based support to adapt their homes.
Originality/value – Documented housing practices reflect both resilience and cultural expression, emphasizing the need for community-inclusive, safe, flexible and climate-adapted housing design approaches. Additionally, by analyzing these adaptive strategies, the study offers insights for the Designing for Flow Framework, promoting housing solutions that align with local contexts and contribute to sustainable development in hazard-prone areas like the Caribbean.

Keywords Affordable housing, Low-income homes, Self-building strategies, Hazard-prone areas, Incremental housing, Climate adaptation, Resilient housing design
Paper type Research paper

1. Introduction

The worldwide housing shortfalls, exacerbated by climate change, pose significant challenges for low-income populations, particularly in regions highly susceptible to environmental hazards. Currently, nearly 40% of the world's population (approximately 3.3–3.6 billion people) live in areas considered highly vulnerable to climate change, with many of these regions already experiencing severe impacts (Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022). The duration, frequency, and/or intensity of extreme events—such as heatwaves, droughts, wildfires, floods, and hurricanes/cyclones—are expected to increase, further affecting the built environment, the housing sector, and households. Despite contributing the least to global emissions, low-income populations and those living in self-organized housing are the most exposed to environmental hazards and face the highest risk of losing their lives (UN-Habitat, 2024).

The Caribbean, one of the most vulnerable regions in the world (United Nations Office for Disaster Risk Reduction (UNDRR), 2023), is facing severe impacts of climate change (Kelder *et al.*, 2025) alongside housing shortages (Greene and Rojas, 2008; Jha, 2007; McTarnaghan *et al.*, 2016; Prevatt *et al.*, 2010; Rojas and Medellin, 2011; United Nations Economic Commission for Latin America and the Caribbean, 2023; United Nations Office for Disaster Risk Reduction (UNDRR), 2023). In Saint Martin, residents encounter significant obstacles in accessing affordable housing that is both suitable for local climate conditions and resistant to related risks, such as recurring tremors, tropical storms, and extreme heat that accelerates material degradation. This shortage has been further compounded by rising construction costs, land scarcity and disputes (World Bank, 2020), energy access issues (Der Sarkissian *et al.*, 2021; TNO *et al.*, 2024), as well as recent climate-related events, including Hurricanes Irma and Maria in 2017 (Collodi *et al.*, 2021; Jouannic *et al.*, 2020; Mehdizadeh *et al.*, 2023; Mycoo, 2020; Der Sarkissian *et al.*, 2021).

Since affordable housing is inaccessible to many, residents are often forced to adopt self-reliant strategies to meet their housing needs. This process, referred to as self-built or self-organized housing, accounts for the majority of housing for low-income populations both globally (Turner, 1972, 1976) and in the Caribbean (McHardy and Donovan, 2016; Mycoo, 2020; Potter, 1994; Potter and Conway, 1997). These developments are particularly common among households with irregular incomes or informal employment, who face barriers to traditional financing (International Recovery Platform and UNDP-India, 2012; Usamah *et al.*, 2014; Wakely and Riley, 2011). Housing development tends to be a long-term, incremental process where residents construct and adapt their homes over time, frequently relying on the assistance of neighbors, family members, or local contractors (Delgado and Antipova, 2010; Gattoni, 2009; Goethert, 2010; Greene and Rojas, 2008; Mota, 2021; UN-Habitat, 2015; Wakely and Riley, 2011). The houses often evolve continuously, following residents' financial abilities and adapting to urgent needs and changing circumstances.

Self-organized housing practices are complex and diverse, resulting in a wide range of home types that navigate challenges related to limited construction knowledge, material availability and quality, financial constraints, and other factors. These challenges are particularly pronounced in climate-vulnerable areas, where structural resistance is a critical concern. Despite these difficulties, collaboration with residents in the building process has been recognized as a key factor in developing affordable homes that address individual household needs while also contributing to local capacity-building (Alexander, 1979; Hamdi, 2010; Harris, 2003; Schilderman, 2004; Turner, 1972, 1976). Strengthening this process through adequate support systems—such as improving risk awareness, planning, technical and construction knowledge, and financial options (Hendriks *et al.*, 2016; Jan and Hurtado, 2022; Karki *et al.*, 2022; Lewis, 2003)—is essential not only for developing affordable homes that are resistant to environmental hazards, but also building capacities and enabling residents to carry out necessary repairs and reinforcements when needed.

Studies of self-organized housing developments provide valuable insights into the challenges residents face, material properties, construction preferences, and local building methods (Delgado and De Troyer, 2011; Iftekhar, 2007; Khassawneh and Khasawneh, 2022; Salama, 2011; Salama and Sengupta, 2011). They also contribute to improving design considerations for future housing developments. In the Caribbean, research has primarily focused on the risks posed by earthquakes and hurricanes, particularly regarding housing forms (Eaton, 1982; Miranda *et al.*, 2020; Mycoo, 2020; Osborne *et al.*, 1992; Prevatt, 1994; Prevatt *et al.*, 2010) and materials used in affordable, self-built housing (Goldwyn *et al.*, 2021, 2022; Goldwyn and Gonz, 2022; Lang and Marshall, 2011; Lochhead *et al.*, 2022a, b; Marshall *et al.*, 2011; Miranda *et al.*, 2020; Mix *et al.*, 2011; Murray *et al.*, 2023; Valdivieso *et al.*, 2024; Venable *et al.*, 2020), with an emphasis on post-disaster studies. Understanding these housing challenges and climate-related adaptations is crucial for developing more resistant affordable housing solutions.

Building on this foundation, the need to develop resilient homes that respond to local climate conditions and adapt to the evolving needs of residents is more pressing than ever. While interest in climate-adaptive and resistant strategies for affordable housing has grown, the ways in which residents construct, modify, and personalize their homes to address local challenges over time remain understudied. These adaptations—ranging from construction techniques and material choices to spatial organization and lived experiences—offer valuable insights into the practical and cultural dimensions of housing resilience. Addressing this gap, this study examines housing in Saint Martin, focusing on how low- and middle-income residents navigate environmental challenges and economic constraints through continuous modifications. By analyzing these evolving housing practices, this research aims to reveal the interplay between durability, functionality, and aesthetic preferences, ultimately informing the development of more adaptable and contextually responsive housing solutions for hazard-prone regions.

2. Methods

This research examines the housing conditions on St. Martin, a small island located in the Atlantic hurricane belt, with a focus on low- and middle-income residents living in small-scale detached housing units who have encountered financial barriers in securing housing. The study was conducted in three phases.

In the first phase, which involved field studies over several weeks during the spring of 2022, researchers reviewed existing literature on affordable housing on the island, conducted ethnographic observations, documented findings through photography, and engaged in discussions with architects, builders, and residents. This phase provided a preliminary understanding of housing activities, the variety of housing developments and self-organized units, and connections with key stakeholders and residents. It helped identify primary building practices and materials, which informed the draft classification of housing types, as well as pinpoint specific areas where these housing types were concentrated (Figure 1).

The second phase, which included field studies conducted over two several-week periods between 2023 and 2024, involved continued ethnographic observations and open-ended, semi-structured interviews with 30 residents. This phase was carried out in collaboration with researchers and students from the University of St. Martin. Participants for the interviews were selected based on information gathered during preliminary field studies and interviews with community gatekeepers, ensuring representation of diverse housing types on the island, with a primary focus on low-income residents and affordable housing. These recorded interviews provided detailed accounts of the history, development, and repair of residents' homes, as well as their future plans. Based on these narratives, researchers and residents collaboratively created drawings of the housing layouts and modifications, mapping changes over time to illustrate the range of building activities (Figure 2).

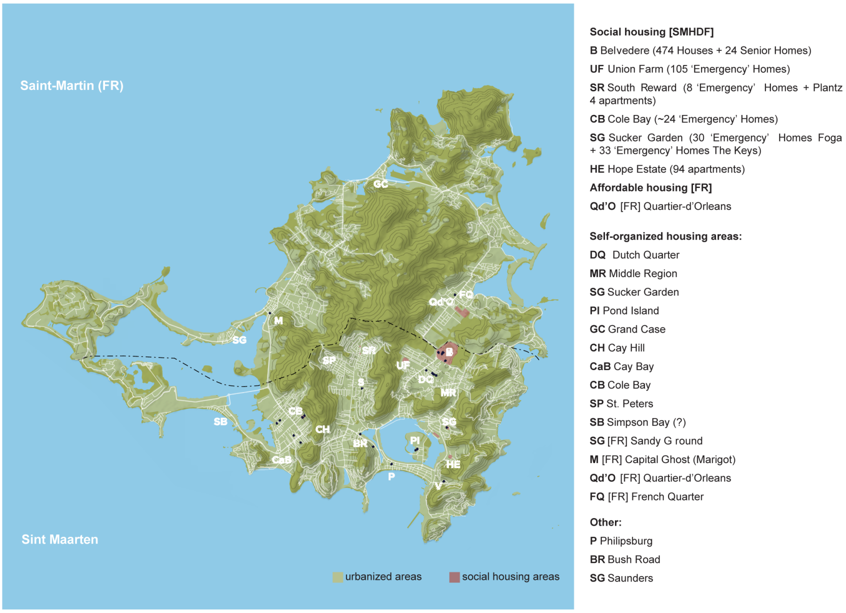


Figure 1. Map indicating social housing, self-organized housing areas, and interviewed houses. Authors' own work, based on Island Map adapted from Gaba (2009)

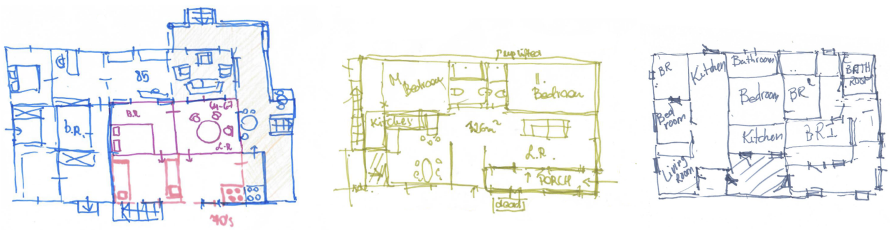


Figure 2. Examples of drawings of the housing layouts and modifications. Authors' own work

In the third phase, preliminary findings prompted the research team to categorize the diverse housing structures based on the primary construction materials used, leading to a proposed classification of housing types. Considering the extensive information gathered and the unique circumstances of each resident, the researchers narrowed the study to six housing units that represent distinct housing typologies. This allowed for a comparative analysis focused on how residents have adapted, modified, and contributed to the durability, functionality, and aesthetics of their homes presented in this article.

This research also has limitations. It provides valuable insights through the in-depth analysis of selected housing types, utilizing ethnographic observations, photographic documentation, and semi-structured interviews with residents. The housing types chosen were based on their relevance and representativeness within the study's context, reflecting the diversity of housing developments on the island. The selection process was informed by strong collaborations with local gatekeepers and networks, ensuring that the findings are grounded in the unique social and cultural context of the community. While the study focuses on a representative sample of housing types, it offers a comprehensive understanding of the dynamics at play within the local housing context.

The narratives of each house were constructed based on information shared by the residents and interpreted by the researchers through drawings. As such, the plans and histories may show slight deviations in terms of specific years, dimensions, and other precise details that could not be recorded or were lost in translation. Additionally, it is necessary to recognize that although the island is also affected by tremors, the primary concern of residents revolves around the risks posed by hurricanes, which is why reinforcement and resistance strategies primarily address hurricane resilience.

Although the research clearly highlights the importance of self-organized housing and the active role of residents in these processes, it is important to note that these practices emerged out of necessity, due to a lack of structural support and inadequate social housing solutions on the islands. The research provides an overview of the residents' active involvement in housing practices, along with lessons on how to improve housing approaches based on their preferences. However, it does not advocate for self-organized, independent housing solutions as a substitute for providing adequate housing support to the residents.

3. Housing flows and designing for a flow

The houses we see today in St. Martin are the result of years of building activities, repairs, and adaptations influenced by financial constraints, climate challenges, and evolving spatial needs. Residents have demonstrated creativity, commitment, and perseverance in constructing, repairing, and modifying their homes. This approach is not unique to St. Martin but is part of a broader trend of dynamic housing processes, resulting in incremental housing, which is observed in many countries across Latin America, the Caribbean, and other regions where access to affordable housing is limited (Greene and Rojas, 2008; Jha, 2007; McTarnaghan *et al.*, 2016). These modifications are part of an ongoing process, referred to as a housing "Flow."

Many affordable housing designs tend to overlook the dynamic nature of housing by offering standardized units that, while resilient to climate challenges, may not fully accommodate unique family dynamics, adapt to households' changing needs over time, or provide a pleasant living experience. The absence of these qualities contrasts with Vitruvius's core design considerations of durability, functionality, and aesthetic appeal (Guyer, 2021; Vitruvius, 1999). Studies of housing flows—how residents interact with, develop, adapt, and modify their homes—can enhance our understanding of local challenges, specifically regarding durability and material resilience, functionality to meet evolving resident needs, and aesthetic appeal to improve both the experience and visual comfort of living spaces.

This article builds on the concept of Designing for Flow (Kuś *et al.*, 2024) to explore how housing changes can reveal a deeper understanding of residents' needs and motivations.

It integrates Vitruvius' design triad with Brand's concept of viewing a house as a system of distinct layers—namely site, structure, skin, services, space plan, and stuff (Brand, 1995)—through the lens of residents' building activities that address these considerations (Figure 3).

By examining existing housing and residents' interactions through various building activities, this study aims to draw lessons for future housing designs, considering aspects such as construction processes, material choices, layouts, and personalization. Insights gained from studying housing flows in St. Martin can inform resilient and more adaptable affordable housing approaches for communities facing similar constraints and challenges.

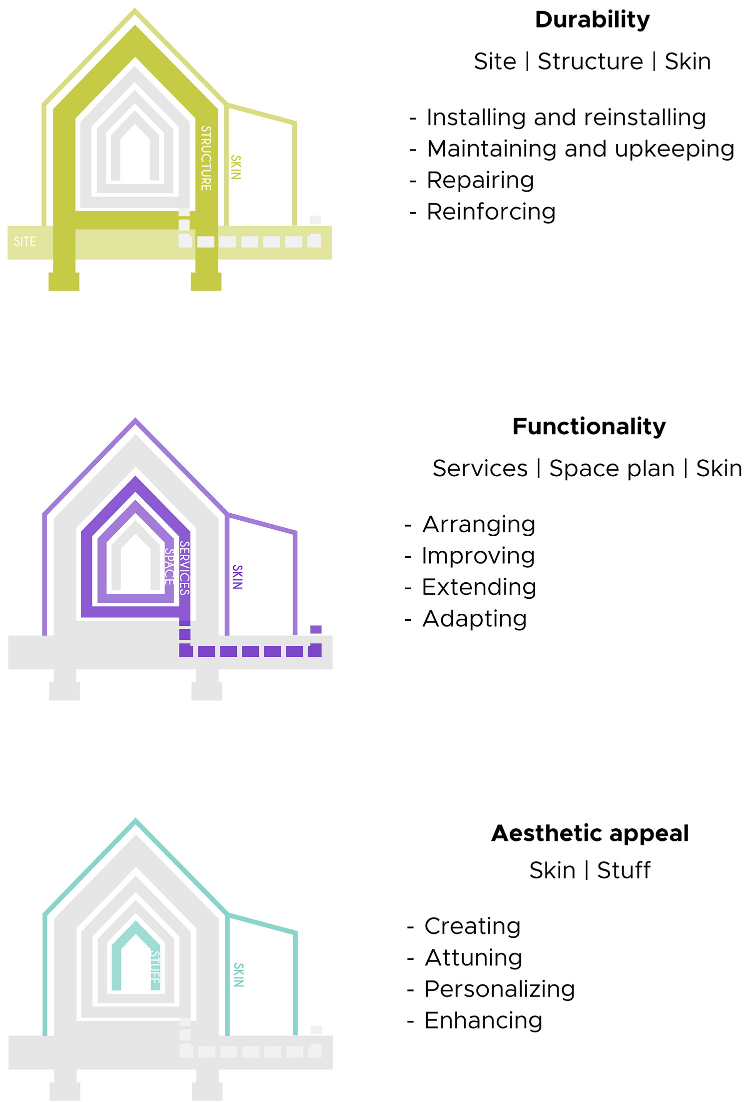


Figure 3. Diagram of building activities connected to durability, functionality, and aesthetic appeal. Authors' own work based on Brand (1995), adapted from Kuś *et al.* (2024)

4. Affordable housing in St. Martin

In the case of St. Martin, the issue of affordable housing is particularly pertinent, as it requires an understanding of the social, economic, and environmental challenges that residents face. The topic of affordable housing worldwide generates considerable debate and diverse opinions, with varying definitions and perspectives (Bredenoord *et al.*, 2014; Daud *et al.*, 2017; Vale *et al.*, 2014). Some studies define affordable housing as housing that is accessible to most residents and costs around 30% of their income (Daud *et al.*, 2017), regardless of income level. However, for this research, affordable housing specifically refers to homes accessible to lower- and lower-middle-income residents living on the island, where financial and environmental challenges shape both the availability and quality of housing.

4.1 Overview of affordable housing and levels of customization

Accessing affordable housing in St. Martin is a significant challenge due to limited apartment availability and a growing demand for such accommodations (World Bank, 2020). The level of customization allowed in these housing options also varies. The most standardized units are pre-built apartments provided by the St. Maarten Housing Development Foundation (SMHDF). Residents with limited financial means have access to a small number of those state-supported social housing units, which come in various sizes but generally do not permit modifications. Due to the scarcity of these options, many residents turn to renting or subletting homes from private owners.

A slightly more flexible option is the limited number of housing units with rent-to-own agreements. While these homes were pre-built with identical sizes and forms, many residents have adapted and customized them over time to better meet their needs. They are also developed by the SMHDF with a promise of ownership after approximately 30 years. An example is the prefabricated housing project initiated after Hurricane Irma (Emergency Housing). Similar types of modifications are permitted for residents developing their own housing units in more organized neighborhoods, particularly where land is leased and the development plan is controlled by an investor. In these areas, homes are often pre-designed but offer limited opportunities for customization.

The most flexible option involves self-built homes, constructed either through formal contractors or by the residents themselves. These homes are built with varying levels of support from formal or informal networks, including friends, local carpenters, or builders. This approach offers the greatest degree of customization, as residents can make decisions and plan their homes based on the specific needs of their households.

4.2 Construction materials and housing types

Houses on St. Martin presents various types of construction processes and techniques and building materials as a result of materials accessibility, financial availabilities of the residents, and other factors. The affordable houses also vary in size and form and have been shaped through various modifications and adaptations performed by the residents over the years. To represent the diversity of housing construction types on the island, this research introduces six housing types organized based on the primary construction materials (Figure 4).

4.2.1 Timber houses. Timber houses are one of the most common types of housing on the island. Historically, wooden housing was popular across the Caribbean due to its affordability and accessibility. These lightweight homes feature wooden walls and roofs, with variations in roof design such as pitched, flat, or inclined. Timber is typically purchased in local stores or imported from nearby islands. Over time, due to the need for frequent maintenance and the hurricane risks, this type of housing became a less preferred choice.

4.2.2 Concrete houses. Concrete houses are a popular housing choice due to the availability of materials, climate considerations, and reduced upkeep. This construction type has become increasingly prevalent in recent years, especially after the devastation caused by Hurricane Irma in 2017. This method involves erecting a concrete frame with walls filled with concrete blocks and typically features a flat concrete roof designed for future vertical expansion.

Figure 4. Proposed housing typology and examples of various housing types. Authors' own work

4.2.3 Timber-concrete houses. Timber-concrete construction combines the two most commonly used materials: concrete and concrete blocks for the walls, with a timber roof structure. This composite approach creates durable, heavy-weight structures while reducing costs by incorporating wooden elements instead of using only concrete. This approach is also motivated by climate performance, as it reduces overheating in comparison to a flat concrete roof.

4.2.4 Prefabricated houses. The next quite common housing type is prefabricated houses. Those pre-casted concrete structures were introduced as a quick and efficient housing solution in the aftermath of Hurricane Luis (1995). These homes were shipped to the island and assembled rapidly to meet urgent housing needs. While initially intended as emergency shelters, many of these homes have persisted over the years.

4.2.5 Steel-framed housing. Another common type of affordable housing is steel-frame construction, based on containers adapted for residential use. This housing type became part of the island's housing stock after Hurricane Luis in 1995, with residents further modifying them to better suit their needs.

4.2.6 Mixed materials houses. In addition to houses built with common materials mentioned above, another significant part of the housing stock consists of homes constructed using a mix of different materials, often combining concrete, timber structures, and other elements. Sometimes, different sections of these houses are built with varied materials. This building approach is often linked to the scarcity of available materials, the gradual accumulation of materials over time, or the process of rebuilding or reinforcing existing structures.

In order to understand the impact of environmental challenges and user modification on the development of different types of houses, this paper has identified exemplary cases for each of the housing types (Figure 5). Specifically, we have selected six houses that represent low-income housing on the island, enabling us to conduct comparative studies on their developments and modifications.

Each of these six houses represents a distinct housing type. While the narratives surrounding each home differ, focusing on these representative cases allows for a deeper exploration of the challenges residents face, as well as the ongoing processes of adaptation and modification over time. By examining these homes, we gain insights into how residents have navigated environmental challenges, financial constraints, and changing needs. This approach highlights the dynamic and evolving nature of housing in St. Martin, providing a clear

	Timber house	Concrete house	Timber-Concrete house	Prefabricated house	Steel-framed house	Mixed materials house
Foundation	wooden poles with lime-based cement	concrete slab	concrete spread footing	precast concrete poles	concrete slab	concrete slab
Walls	mahogany or kousher wood	concrete blocks	concrete blocks	precast concrete	steel beams (40 ft container)	timber; concrete blocks
Walls skin	plywood siding (T1-11)	plaster	plywood siding (T1-11)	-	steel panels	plywood siding (T1-11)
Roof	timber (2x4)	concrete slab	timber	precast concrete	steel beams (40 ft container)	timber (2x4)
Roof skin	zinc plates	-	zinc plates	-	steel panels	zinc plates

Figure 5. Selected exemplary housing types and materials overview. Authors' own work

foundation for understanding the broader housing flows and construction processes discussed in the following sections.

5. Narratives of housing flows

5.1 Construction process

In St. Martin, as in other Caribbean islands, many homes were shaped by limited financial resources. Since constructing a large, durable house all at once was beyond the means of many residents, different strategies were employed to reduce costs. These included a gradual construction process, opting for less expensive building materials, reducing labor expenses, or a combination of these approaches.

To reduce labor costs, community support played a crucial role for many residents. Homes like the Timber House and Concrete House were built with the assistance of family and friends through a local tradition known as "jollification," where community members work together in exchange for food and drinks provided by the host (Hale, 2015; The World Bank, 2017). This process took varying amounts of time depending on the particular case and the skill of the community; however, it would usually be a more time-consuming and gradual process in comparison to houses built by professional builders. Although residents were often constrained by financial limitations and the availability of materials in local stores, this process allowed for a high level of customization. In contrast, not all residents had the same freedom to personalize their homes. For example, the Prefabricated House and Timber-Concrete House were initially designed as standard units by external practitioners, which limited residents' influence over the final layout and features. These prefabricated and steel-framed homes have emerged as practical solutions for post-hurricane reconstruction, as their components are manufactured off-site and can be quickly assembled to provide immediate shelter and structural integrity.

5.2 Durability – materiality

5.2.1 Unit development. Housing construction in St. Martin has evolved to address environmental challenges, particularly hurricane resilience, flood protection, and heat management. Historically, mahogany or kosher wood was traditionally used for timber structures, with larger elements placed in the building's corners to enhance hurricane resistance. One of the climate adaptation techniques already adopted at that time was raising the house to protect it against water, as seen in early 20th-century timber houses. As one resident recalls:

> It used to be on wood. On pegs [referring to the piles], because of the rain. And you're able to go play under the house. Anyway . . . [it's] because of the rain. There used to be a lot of flooding, I gather. So all the houses were on wooden pegs . . . [timber house]

The wooden piles were strengthened with lime-based cement, a locally sourced material made from limestone and gravel, to improve water resistance. As time passed, more resilient materials such as precast concrete replaced wood, providing stronger, water-resistant foundations while following the same approach of raising the houses. This also allowed for adaptation to uneven terrain, as seen in the case of the Prefabricated Panels House, which utilized different pile heights for this purpose.

The construction techniques on the island are diverse, with common materials including concrete, concrete blocks, and timber. The frequent threat of strong storms has made concrete structures increasingly popular due to their durability and lower maintenance requirements. In the past, residents made their own concrete blocks using forms and beach sand to reduce costs, but this approach compromised durability because of the unsuitable grain size and high salt content of the sand.

Today, the methods of building with concrete have evolved. Concrete slabs reinforced with steel, as seen in the Concrete Frame and Timber-Concrete Construction Houses, have become the standard foundation material, providing improved resistance against storms. Two distinct construction processes are now used for concrete walls: one in which the frame is built first and blocks are added later, and another where the blocks are laid first before pouring concrete—the latter being preferred for its enhanced structural integrity. Many residents also reinforce concrete blocks with steel bars when feasible for added strength. Additionally, modern concrete houses often feature a ring beam that connects the walls, further enhancing their resilience to extreme weather conditions.

Roof shapes have also adapted to environmental conditions. Flat concrete roofs, like those in Concrete Frame Houses, are designed to allow future expansions while mitigating storm damage. In contrast, slanted timber roofs, common in homes like the Mixed Materials House and Timber-Concrete Construction House, are covered with zinc, which reflects heat and improves ventilation in the island's warm climate. Another risk adaptation strategy involves constructing separate roofs over porches to ensure that, in the event of a hurricane, damage to the porch roof does not impact the main structure.

5.2.2 Additions and adaptations. Housing developments in St. Martin illustrate a diverse range of material approaches and adaptation motivations, deeply influenced by family circumstances, work-related needs, cultural adaptations, and climate challenges (Figure 6). The housing construction methods also affect the potential for future expansions, and the choice of building materials is linked to the types of modifications residents make.

Concrete provides a robust foundation for various types of expansions, both vertical and horizontal, using a range of materials. Common adaptations often involve adding extra rooms, as seen in the Timber-Concrete House (Figure 6), or even additional floors if financial resources allow. These modifications are typically motivated by the need to accommodate growing or multi-generational families, as demonstrated in the Concrete House.

Homes that are originally constructed with less resilient materials, such as Timber House or Mixed Materials House, often expand their houses by building additions using more resistant materials like concrete. These extensions increase the usable space and enhance the home's safety against weather challenges, such as strong storms. For homes initially built with timber, transitioning to concrete for extensions is an important step in ensuring durability and protection, although it often requires residents to save up for these more expensive materials.

Timber remains a practical choice for certain types of expansions. For houses where additional reinforcement is not necessary, like in the Timber-Concrete House or the

	Timber house	Concrete house	Timber-Concrete house	Prefabricated house	Steel-framed house	Mixed materials house
Foundation and slab	-installing a back slab extension (1975)-installing a front slab extension as a porch (1980s)	-installing a back slab extension (1964)-installing a slab extension (1980)	-installing a side slab extension (1995)-installing a back slab extension (2013)	-installing a front and side slab extension (1999) -installing a back slab extension (2001)	-installing a side slab extension (2019)	-installing a side slab extension (2005)
Walls	-installing additional concrete walls in the back (1975)-installing additional timber wall structure in the front (1980)	-installing additional concrete walls in the back (1964-67)-installing additional concrete walls (1980-85) -installing additional concrete walls on the upper floor (1991)	-installing additional timber walls on the side (1995)-installing additional timber wall structure in the back (2013)	-installing additional timber walls in the front and on the side (1999)-installing additional timber wall structure in the back (2001)	-installing additional container (2019)	-installing additional concrete walls on the side (2005)
Walls skin	-painting the walls (1975)	-painting the walls (1967), -painting the walls (1985)	-installing a cover over the timber extension (1995)	-installing a cover over the timber extension in the front and on the side (1999)-installing a cover over the timber extension in the back (2001)	-	-painting the walls (2005)
Roof	-installing an concrete slab in the back (1975)-installing a timber roof extension in the front (1980)	-installing an concrete slab in the back (1964-1967), -installing an concrete slab (1980-85)	-installing an extension timber roof extension on the side (1995)-installing a timber roof extension on the back (2013)	-installing an extension of the roof in the front and on the side (1999)-installing an extension on the back (2001)	-installing additional container (2019)-installing additional roof extension between the two containers (2019)	-installing a timber roof over the extension on the side (2005)
Roof skin	-installing a cover over the timber extension (1980)	-	-installing a cover over the timber extension (1995)-installing a cover over the timber extension (2013)	-installing a cover over the timber extension (1999)-installing a cover over the timber extension (2001)	-installing zinc cover over additional roof (2019)	

Figure 6. Overview of housing additions and adaptations. Authors' own work.

Prefabricated House, timber and plywood are used for creating new spaces. Additions built in wood are usually more affordable and quicker to construct. Timber is also employed for less critical extensions, such as laundry rooms, additional kitchens, or porches, which enhance living conditions while maintaining a cost-effective approach.

An alternative expansion method is exemplified by the Steel-framed House, where the homeowner utilized modular, prefabricated elements to extend the living space. By adding another container and building a connecting roof, they increased the home's layout. To enhance hurricane resistance affordably, the homeowner innovatively repurposed discarded street lamp poles as steel beams, which were welded between the containers and filled with concrete.

5.2.3 Maintenance: upkeep and repairs. The upkeep and repairs across various housing types in St. Martin reveal how residents interact with their homes to combat weather-related challenges such as sun exposure, salty sea breeze, strong winds, torrential rains, hurricanes, earthquakes, and the natural aging of structures (Figure 7). These factors influence the lifespan of materials, making it shorter. The residents also report that the material quality available on the island is lower compared to other places. The level of maintenance needed depends largely on the materials used and their vulnerability to environmental damage.

Houses using timber demand frequent upkeep due to the organic nature of wood, which is susceptible to decay, rot, and insect damage. Weather cycles, especially intense sun exposure

	Timber house	Concrete house	Timber-Concrete house	Prefabricated house	Steel-framed house	Mixed materials house
Foundation and slab	-installing wooden floor (1975)-reinforcing the foundations by adding cement (1990s)	-	-	-installing tiles (1999) -addressing septic tank issues (2001)	-installing concrete slab inside the container for hurricane resistance (2017)	-installing anchors in the slab as an additional hurricane measure (2017)
Walls	-repairing and reinforcing rooting posts (1990s)	-	-	-	-	-repairing hurricane damages (2017)
Walls skin	-repairing skin damaged due to rooting (1990s)	-painting the walls (2018)	-replacing -painting the walls (2023)	-painting the walls (1999)-replacing hurricane damages (2017)	-protecting the walls against corrosion (2017)-repairing damages after hurricane around windows and doors (2017)-replacing the door (2017)-painting the walls with a protective coating (2024)-installing new windows and doors (2024)	-
Roof	-repairing significant hurricane damages (1950s)-repairing hurricane damages (1995)-repairing and reinforcing of rooting elements (1990s)-repairing hurricane damages (1995)-unable to repair significant hurricane damages (2017)	-repairing roof damages and concrete cracks (2018)	-	-	-	-repairing significant hurricane damages (2017)
Roof skin	-repairing significant hurricane damages (1950s)-repairing hurricane damages (1995)-repairing and reinforcing of rooting elements (1990s)-repairing hurricane damages (1995)-unable to repair significant hurricane damages (2017)	-	-	-repairing hurricane damages (2017)	-installing new zinc (2024)	-repairing hurricane damages (2017)-repairing leakages (2023)

Figure 7. Overview of housing upkeep and repairs. Authors' own work

and the swelling caused by the salty sea breeze accelerate the degradation of timber. Wooden elements must be regularly treated to prevent these issues, and residents often perform maintenance to protect the structural and exterior wooden components. Residents also inspect the connections between rafters and roof coverings, especially before the hurricane season.

Repairs are often necessary after hurricanes, and timber houses tend to require the most significant structural fixes, especially to roofs and posts (Figure 8C). The residents of Timber House reported frequently repairing roof elements or dealing with wood rot by removing softened sections and filling them with a mixture of wood fragments and glue. That house suffered significant damages after Irma in 2017 and was not repaired or inhabited afterward.

Concrete and steel homes, on the other hand, require less maintenance. In these structures, upkeep is primarily focused on water protection, with residents applying coatings or repainting to guard against water infiltration. Recoating helps prevent water damage and the corrosive effects of salt, which can cause paint to swell and crack. Steel frame houses also require anti-

(a) (b) (c)

Figure 8. Examples of damaged elements (A) damaged concrete piles; (B) patched concrete ceiling; (C) damaged wooden rafters. Authors' own work

corrosion treatments to prevent rust, reflecting how different materials dictate the type and frequency of upkeep.

In the event of a hurricane, roofs are typically the most susceptible to damage. Concrete roofs tend to perform better in this regard. Residents of Concrete and Timber-Concrete houses also reported necessary repairs, primarily related to fixing cracks in the concrete (Figure 8A). For Concrete houses, this involved filling the cracks with cement mixes or specialized mixes available in local stores (Figure 8B).

5.2.4 Reinforcements. Building strategies and practices in St. Martin have evolved over the years to construct homes that can withstand the island's challenging climate. Residents have taken an active role in reinforcing their houses to ensure longevity and preparedness for tropical storms. These reinforcement strategies vary depending on the materials used and focus primarily on the roof, the building's base, and the connections between various structural components.

One key strategy involves using stronger and heavier roof elements. For instance, in the Timber House, the wooden rafters were upgraded to larger ones, while the Steel House employed innovative techniques like connecting containers with additional roofing and filling steel beams with concrete for greater stability. Many homes also improved the roof-to-rafter connections by replacing nails with screws or fasteners, which provide a stronger hold during intense storms.

Securing the connection between the roof and walls is another critical safety measure. This is often achieved using reinforced concrete. For example, a modern approach in the Concrete House is the use of a ring beam, now widely adopted to bolster storm protection. In other homes like the Timber-Concrete House, roof rafters are anchored in concrete, preventing them from being lifted by hurricane winds.

Another technique focuses on reinforcing the base of the building and anchoring it to the ground, particularly for lightweight structures, to prevent them from being uprooted during storms. This is often achieved by adding concrete for weight and stability. The Timber House, for example, enhanced its foundation with concrete to improve resistance, while the Steel Frame House achieved additional storm resilience by adding a concrete slab. The Mixed Material House utilizes alternative reinforcement methods to strengthen their bases using anchors attached to concrete foundations. They are used to secure straps around the house, tying it down to prevent it from being lifted or blown away during hurricanes.

Another significant risk residents address is the vulnerability of windows and doors. Many windows are protected by installing wooden shutters or covering them with plywood to shield against flying debris like roof tiles or handles. In well-sealed concrete houses, it's crucial to manage internal pressure during storms. This is often done by leaving two windows slightly open on opposite sides, which doubles as an emergency ventilation method. Additionally, after Hurricane Irma, many residents modified their doors to open outward, reducing the risk of them being forced open by strong winds.

5.3 Functionality – form and layout

5.3.1 Initial house. The initial layouts and forms of the six houses in St. Martin reveal varying degrees of complexity, with differences in size, indoor amenities, outdoor spaces, and placement on their respective plots (Figure 9).

The positioning of the initial house development on the plot has a significant impact on future expansion possibilities. Most of the houses in this study were centrally located, a layout that facilitates growth in multiple directions. Exceptions include the Steel Frame House, which was aligned to the side, and the Mixed Materials House, which was set further back—both choices leaving room for work activities or potential additions.

In terms of size, the Timber House and the Concrete House began as relatively simple units, consisting of just a bedroom and a living room. These modest layouts reflect limited finances during their initial construction, focusing only on essential spaces. Despite budget constraints, the Mixed Materials House featured two bedrooms and corresponding bathrooms, constructed with less expensive materials. In contrast, the Prefabricated Panels, Timber-Concrete, and Steel Frame Houses were constrained by standardized, pre-designed plans.

The layouts of the houses reflect cultural preferences, adhering to a logic of increasing privacy. Entrances typically lead through a porch—often an elevated, roof-covered space visible and accessible to guests. From the porch, the main entrance opens into the living room, a semi-private area often connected to the kitchen and bathroom, which serve as boundaries to more private spaces like bedrooms. Kitchens often feature back doors for functional use or emergency access. Additionally, outdoor areas are frequently used for work-related activities, as seen in the Steel Frame and Mixed Materials Houses.

5.3.2 Adaptations and modifications. Many houses in St. Martin were initially influenced by family growth and financial constraints, starting as smaller units and gradually expanding over the years (Figure 10). The incremental growth illustrates how these homes began as simple structures and were expanded over time with additional rooms and amenities. For example, both the residents of Timber House and Mixed Materials House initially focused on

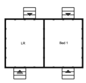
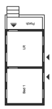
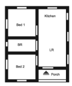
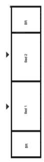
	Timber house	Concrete house	Timber-Concrete house	Prefabricated house	Steel-framed house	Mixed materials house
initial layout						
position	rectangular, in the centre	rectangular, in the centre	rectangular, in the centre	rectangular, in the centre	rectangular, aligned to the side	rectangular, in the back
indoor spaces	bedroom, living room	bedroom, living room	2 bedrooms, open living room with kitchen, bathroom	2 bedrooms, open living room with kitchen, bathroom	2 bedrooms, 2 bathrooms	2 bedrooms, 2 bathrooms, open living room with kitchen
outdoor spaces	outdoor kitchen, outdoor bathroom	small porch, outdoor bathroom and kitchen	small porch, garden on the side	small porch, garden in front and in the back	outdoor kitchen	garden used as workshop

Figure 9. Overview of initial housing layout. Authors' own work

adding missing essential amenities, such as a larger or indoor kitchen (Figure 11). Other houses, such as Concrete, Timber-Concrete, and Prefabricated Houses, required expansions to accommodate growing families by adding extra bedrooms. The Concrete House, in particular, underwent a significant transformation, starting as a two-room structure and evolving into a five-bedroom home with an extended porch. This gradual expansion sometimes resulted in complex layouts, with rooms being added one after another over the years, leading to many spaces functioning as pass-through areas. This house was also designed to allow for an additional floor to accommodate future generations; however, this expansion was never completed due to a lack of interest from younger family members.

In contrast, the Timber-Concrete House and Prefabricated House underwent only minor modifications, maintaining their original layouts with small updates like adding a laundry room or an outdoor kitchen, focusing on functional improvements rather than substantial expansions (Figure 11). In homes like Concrete House, Timber House, and Prefabricated House, porches were added as part of incremental expansions, serving as transitional spaces between indoor and outdoor living areas.

Another type of modification is related to work activities, as seen in the Steel Frame House. These modifications were driven by the need for additional storage and workspace for a repair workshop. This was achieved by adding an extra container some distance from the original unit and covering the space between them. The Steel Frame House also faced a unique challenge due to issues of land tenure, necessitating relocation to a different plot. The resident managed to move the entire structure using a crane, keeping the house intact and functional at its new location.

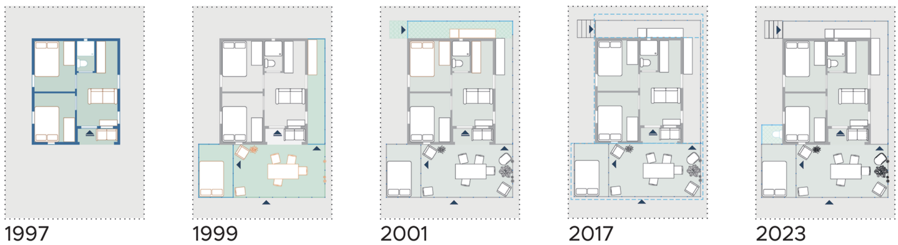


Figure 10. Detailed studies of the changes over the years of the Prefabricated House. Authors' own work

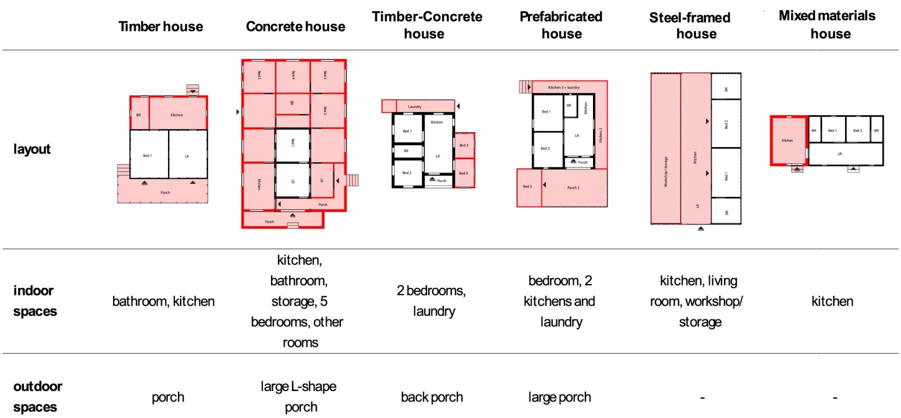


Figure 11. Overview of changes in housing layouts. Authors' own work

5.4 Aesthetics – spatial preferences and attunement

5.4.1 Building preferences. The aesthetic appeal of houses in St. Martin is shaped by personal preferences, cultural practices, financial constraints, and environmental factors, reflecting the island's rich cultural diversity.

The location of each plot influences aesthetic choices, with proximity to natural elements such as water, wind, and surrounding greenery impacting decisions about the form and materials of homes. Residents often enhance their surroundings with gardens featuring fruit trees, such as mangoes, workshops for appliances or car repairs, and privacy elements like fences or latticework. These design features reflect the ambiance residents wish to create in their homes.

Climate considerations significantly influence the form and appearance of houses. Older residents tend to prefer wooden roofs, which are more effective at coping with extreme heat, while large windows facilitate natural cooling breezes, reducing reliance on air conditioning. Shaded porches are another prominent feature, protecting against harsh sunlight while enhancing the enjoyment of outdoor living spaces.

Durability concerns, especially following the hurricanes of 1995 and 2017, have also influenced the aesthetic appearance of homes. While older residents still favor wooden structures—often adorned with decorative fretwork along the roof edges—many have begun opting for more durable materials like concrete and steel to safeguard their properties. This shift has resulted in bunker-like designs with lower ceilings that can lead to overheating.

Moreover, homes serve as symbols of status, visible to others from the outside, prompting many residents to curate their homes with this consideration in mind. Aesthetically, vibrant paint colors are commonly used not only for their visual appeal but also for practical reasons, such as protecting the house from water damage, further contributing to the island's colorful architectural identity.

5.4.2 Attunement, personalization, and enhancements. Family size, strong ties, and a challenging housing market particularly for young and older individuals have significantly influenced the appearance and structure of homes in St. Martin. Multi-generational living is common on the island, leading to homes with distinct living areas, multiple entrances, and additional bathrooms to cater to diverse needs and offer a degree of independence to family members. Family memories also play an important role in shaping the identity and personal expression of these homes, often resulting in the thoughtful curation of spaces. As one resident recalls:

> [. . .] [a family member recalling the house of the responder] [. . .] and you had, um . . ., a dresser, I mean, a cabinet with your dishes . . . You had a round table, in the corner . . . and pictures, pictures of Hyde Lacy, and, um, . . . what was the president? What's his name? Um . . . John F. Kennedy. [timber house]

The gradual development of homes often resulted in visible differences between sections built at different times. These expansions included additional bedrooms, bathrooms, or other functional spaces. Outdoor kitchen extensions were sometimes added to support cultural cooking practices. To create a cohesive look from the street view, some residents actively connected these parts using features like porch extensions, as seen in the Concrete House and Prefabricated House.

The need for functional workspaces, particularly for repair workshops, has also shaped the visual experience of many homes. Appliances or cars awaiting repair are often stored for spare parts, occupying substantial areas. Some residents store these items in yards or garages, while others place them in front of the house or on nearby empty plots. Although this practical use of space may impact the home's visual appeal, it is essential for many households.

Privacy and security concerns also significantly influenced the appearance of homes in St. Martin. Many residents installed anti-burglar bars on street-facing windows, allowing them to remain open at night or during absences for ventilation. Larger louvered windows, made from glass or steel, are also common for their airflow benefits and storm resistance. The bars can also be installed on entrance doors or even replace them entirely, creating semi-open spaces for better ventilation, as seen in the Steel Frame House. Additionally, the bars often serve as a base for hurricane protection by holding plywood sheets between the bars and windows.

The aesthetic appeal of homes in St. Martin is also shaped by residents' efforts to maintain, personalize, and beautify their living spaces. For example, the resident of the Concrete House, despite their advanced age, continues to regularly paint the home and tend to the surrounding plants. Similarly, the resident of the Prefabricated House carefully maintains the external space, decorating it with greenery and adding elements such as curtains for various occasions.

This ongoing engagement between residents and their homes reflects a broader pattern of self-organized housing practices in Saint Martin, where residents continuously adapt their living spaces in response to personal, financial, and environmental factors. This dynamic housing process, described as "flow," highlights the evolving nature of housing.

6. Discussion: lessons for designing for a flow

As presented in the study, the houses in Saint Martin "flow," meaning that they evolve over time, shaped by the active involvement of residents who continuously add, repair, maintain, modify, and reinforce their homes to improve safety, comfort, and appearance. This process aligns with Vitruvius' design considerations of balancing durability, functionality, and aesthetic appeal. Based on the challenges faced by residents and the actions they take to address these issues, the study offers valuable lessons that can inform future housing developments. These include the importance of involving residents in the housing process, utilizing diverse locally available materials, and understanding the climate-related implications of using such materials. Additionally, the study highlights the significance of housing typology, form, layout, and space curation in creating resilient and adaptive living environments.

6.1 Role of residents in housing processes

Many St. Martin's residents actively participate in modifying, repairing, and beautifying their homes, often with the help of friends or family members (a practice known as "jollification"). This collective effort not only helps reduce costs but also strengthens social bonds and promotes knowledge sharing, which can be invaluable in the context of hazard-prone self-organized housing. It fosters a sense of belonging and self-expression among residents. However, a key challenge to consider is the potential impact on construction quality. Acknowledging this, similar to other studies (Bredenoord *et al.*, 2014; Bredenoord and van Lindert, 2010; Greene and Rojas, 2008; McTarnaghan *et al.*, 2016), the authors highlight the importance of community participation, emphasizing its role not only during the design phase but throughout the entire lifecycle of the homes.

6.2 Material choices

The most accessible and commonly used construction materials on the island are concrete and wood. Concrete is often seen as more durable during storms due to its heavy weight, strong connections between parts, and perceived low maintenance requirements (Goldwyn *et al.*, 2021; Lochhead *et al.*, 2022a, b; Prevatt *et al.*, 2010). However, its effectiveness relies heavily on the quality of the materials and the construction process. On the other hand, wood tends to perform better during earthquakes, and its components are easier to repair or replace when damaged, which can be more difficult with concrete. A key takeaway from this study is the observed practice of using different materials for different parts of the building, depending on their function and expected lifespan. This hybrid approach offers a cost-efficient balance between storm-resistant concrete and easily repairable wooden elements.

6.3 Housing typology, form, and layout

The preferred housing typology in St. Martin remains private, single-family, small detached houses, but in areas where land is scarce and difficult to acquire, this model presents challenges. While multi-story apartment buildings are not a popular choice, they offer a more efficient solution in terms of both land use and costs.

Houses with modern, cubical forms and flat concrete roofs are often preferred because they facilitate future vertical expansions. However, these designs perform poorly in the local climate, leading many residents to rely heavily on air conditioning. In contrast, sloped roofs with larger spaces can enhance light reflection and ventilation, while outdoor shaded areas, such as porches, improve living conditions. There are many effective climate-adaptive strategies that can help lower indoor temperatures and make homes more suited to the environment (Bulbaai and Halman, 2021). A promising solution is a hybrid approach, using different forms based on the function of each space, as proposed in the material section.

The layouts of self-organized houses often evolve over time, shaped by the active involvement of residents. Despite financial constraints and tenure insecurities, residents have found ways to develop their homes according to their needs, building incrementally—starting with units that meet basic needs and gradually expanding as resources allow, ideally without sacrificing material quality or quantity (Lang and Marshall, 2011; Marshall *et al.*, 2011). This study emphasizes the importance of an incremental approach, beginning with simple and resistant units that adapt over time. Planning for future expansion should be incorporated into the initial decision-making process, as the placement of the building on the plot, along with communication pathways, can significantly affect the space's functionality. Additionally, planning for multigenerational living—such as designing separate units within a house for elderly family members, young adults, or potential rental spaces—is a key component of this approach. Moreover, spaces for repair workshops or other in-home economic activities should be factored into future housing plans.

6.4 Space curation and personalization

Given that each household has unique needs, homes must be adaptable to accommodate the specific requirements of the families living in them. This adaptability also allows for the expression of individual backgrounds, traditions, and preferences, which are deeply embedded in the culture and ethnic diversity of St. Martin. Personalization plays a key role in shaping identity and fostering a sense of ownership and care for the spaces. It includes not only interior modifications but also the maintenance and management of surrounding areas. Actively beautifying and personalizing their homes is a common practice among residents, reflecting their connection to the space and their desire to create environments that align with their values and lifestyles.

The study highlights how residents actively adapt their homes through various activities. Implementing a design framework like Designing for Flow—which supports these activities while balancing durability, functionality, and aesthetics—enables residents to build and modify their homes incrementally. This approach not only fosters the homes' evolution in response to changing needs but also encourages cultural expression. A key component of Designing for Flow is finding a balance between areas of the building that can be adapted by residents and those that must remain fixed. This ensures safety in the face of hazards while providing the flexibility needed for continuous, context-specific adaptations.

7. Conclusion

This research underscores the pressing need for resistant, climate-adapted housing developments in vulnerable regions, particularly for low-income populations. As demonstrated in the case of Saint Martin, limited access to affordable, durable housing forces residents to rely on self-organized construction, navigating financial constraints, environmental challenges, and evolving household needs. This process results in a diverse range of self-organized housing types that reflect both practical adaptations and cultural expressions.

By examining self-organized housing in Saint Martin, this study highlights how residents actively modify their homes over time, employing cost-saving strategies such as incremental construction, material substitution, and community support networks like jollification. The study also reveals the impact of increasing climate risks on housing materials and construction techniques, showing a shift from wood to more durable materials like concrete, as well as structural reinforcements to withstand extreme weather conditions. These adaptations, while resourceful, also present challenges, such as inefficient layouts or material vulnerabilities.

Furthermore, this research emphasizes the importance of collaboration between residents, local stakeholders, and policymakers to strengthen housing resilience. Supporting locally driven construction efforts with technical knowledge, safer building practices, and access to quality materials can enhance long-term durability while preserving affordability and cultural relevance. Striking a balance between structural safety and flexible adaptation is key to creating homes that can withstand environmental hazards while evolving with residents' changing needs.

Ultimately, this study contributes to broader discussions on designing adaptable, contextually responsive affordable housing. By drawing lessons from the lived experiences of Saint Martin's residents, it offers valuable insights for future housing strategies in other hazard-prone regions. Balancing between structural safety and flexible adaptation, as presented in the Designing for Flow approach, supports creating homes that can withstand environmental hazards while evolving with residents' changing needs. Moving forward, it is crucial to integrate community-based approaches that build local capacities, recognize the value of self-organized housing, and provide the necessary support systems to ensure safer, more sustainable, and climate-resilient homes.

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