Future Cities and Environment

Enhancing Climate Resilience Against Flooding in Housing Design Through Synergistic Strategies in Pakistan

TECHNICAL ARTICLE

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ABSTRACT

The ever-evolving threats presented by climate change compel us to rethink and restructure our built environment, particularly housing designs, to imbue them with resilience and adaptability. In this research, this study has embarked on an exhaustive review of scholarly works to identify design harmonies that can enhance the resilience of housing structures under fluctuating climate circumstances, particularly flooding results from unexpected heavy rains. The study's purview extends to diverse case studies from Northern and Southern parts of Pakistan experienced unprecedent rains and flooding, elucidating the unique obstacles and environmental variances across these regions.

The literature review spans across several disciplines, exploring resilience in housing design from architectural, environmental, health and socio-economic angles. It provides an in-depth examination of established methodologies and innovative trends, with an emphasis on merging ancestral wisdom with modern advancements. This holistic approach underscores the significance of community-based design solutions, active community involvement, and policy structures in cultivating resilience.

The case studies from different flood affecting regions of Pakistan serve as practical examples, shedding light on the unique climatic adversities and identifying 14 critical housing defects caused by natural disasters. By juxtaposing these diverse climatic settings, this study determine design and protection guidelines that can be customized to cater to each region's specific requirements, fostering a resilient housing infrastructure capable of weathering climate change impacts.

In conclusion this study underscores the importance of adopting both immediate and long-term strategies for housing design in response to climate change. By synthesizing the valuable insights gleaned from the literature review and case studies, a set of recommendations for architects, urban planners, and policymakers are suggested to promote resilient housing design, not only within Pakistan but on a global scale.

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1. INTRODUCTION

Climate change is one of the global challenges of our time, with far-reaching impacts on the environment, society, and the economy. One critical area that requires urgent attention is the resilience of affordable housing in the face of climate change and resultant flooding. Affordable housing provides shelter to millions of people, and its vulnerability to flooding is a threat to the livelihoods of individuals. The challenge stems from the need to adapt to the effects of climate change while balancing the costs and availability of resources. This challenge is further complicated by the fact that low-income households are often located in areas most susceptible to the impacts of climate change, particularly overflow of rivers and flooding. Therefore, addressing the challenges of resilience in affordable housing is crucial in ensuring that vulnerable communities have access to safe and sustainable housing that can withstand the impacts of climate change and resultant overflow of rainwater and flooding. This essay will explore the challenges of resilience in affordable housing in the face of climate change and suggest strategies that can be employed to mitigate the impacts of climate change on affordable housing.

According to a study by Baloch (2022) published in The Guardian, the ongoing floods in Pakistan are predominantly attributed to climate change. The exceptional land temperature fluctuations caused by climate change within Pakistan have intensified monsoon precipitation, resulting in an unprecedented accumulation of water in the nation's northern and southern regions (Baloch, 2022). This has led to record-breaking floods within the Indus River basin. Numerous scientific investigations have demonstrated that climate change disproportionately impacts monsoon-affected areas compared to other regions worldwide. The study further stresses that it is time for the global community, particularly those nations with high carbon emissions, to take responsibility also on developing a long-term, sustainable adaptation strategy to combat the recurring effects of climate change-induced disasters in the future. Deforestation is acknowledged as a factor that exacerbates flooding and landslides, and regrettably, Pakistan has the second-highest deforestation rate in Asia. At the time of Pakistan's inception in 1947, forests covered 33 percent of the country's total land area; however, this figure has now dwindled to a mere 5 percent (Mir, 2022).

Addressing the issues of climate change and resulting flooding study of Rannard (2022) referred to the studies of experts and stress that the devastating floods in Pakistan are a "wake-up call" to the world on the threats of climate change (Rannard, 2022). However, it is worth mentioning that Pakistan is not a significant contributor to global warming, but it is on a high-growth trajectory of carbon emissions linked to fossil fuel use. Pakistan contributes less than 1% of the global greenhouse gases that warm our planet, but its geography makes it extremely vulnerable to climate change.

Numerous studies have documented the challenges of affordable housing in the face of climate change. For example, a study by the National Low-Income Housing Coalition (NLIHC) found that affordable housing is disproportionately located in areas that are vulnerable to natural disasters such as floods, hurricanes, and wildfires (NLIHC. 2022; Cornell et al., 2020). Another study conducted by the United Nations found that climate change will increase the risks of displacement and homelessness, particularly in low-income communities (UNDP, 2021).

The challenge of resilience in affordable housing stems from the need to adapt to the effects of climate change while balancing the costs and availability of resources. For example, it may be necessary to invest in measures such as improved insulation or flood-proofing, but these measures can be costly and may not be feasible for low-income households. Moreover, low-income households are often located in areas that are most susceptible to the impacts of climate change, such as flood-prone areas or regions with extreme weather conditions. Pakistan in general, particularly in the present time, is already facing multifaced challenges and problems related to the housing shortage, besides the affordability of buyers, there is a big gap between housing supply and demand. Studies have shown that the housing demand in Pakistan is increasing with time, and currently, Pakistan is facing a housing deficit of 10 million units. However, the total housing shortage percentage of the population is 24% which is significantly higher than the neighbouring countries with similar demographics, i.e., India at 12% and Bangladesh at 18% (Qureshi et al., 2022).

Concerning the housing demand and growing population, the study of IIPS (2022) mentioned that Pakistan's population living in urban areas, already highly exposed to pollution and climate change, will increase from 37% in 2020 to 60% in 2050 (IIPS, 2022). To ensure cities become more liveable, urgent reforms are needed for more integrated land use planning and increased investments in municipal services and energy efficiency, and clean transportation. Deforestation is a particular problem.

Various studies have demonstrated the link between affordable housing and climate change resilience. For instance, a study conducted by the National Low-Income Housing Coalition (NLIHC) found that low-income households are disproportionately impacted by natural disasters, such as hurricanes and floods, which can cause significant damage to affordable housing (NLIHC, 2022). Another study by the US Green Building Council (USGBC) found that green building strategies, such as energy-efficient design and the use of renewable materials, can improve the resilience of affordable housing to climate change impacts (USGBC, 2020; USGBC, 2021).

Furthermore, the need to address climate resilience in affordable housing has been recognized by various international organizations and initiatives. For example, the United Nations has identified affordable housing as a critical area for climate change adaptation and has emphasized the need to integrate resilience strategies into housing policies and practices (UN-Habitat, 2022). Additionally, the 100 Resilient Cities initiative, which aims to build resilience in urban areas, has highlighted the importance of affordable housing in promoting resilience to climate change (100RC, 2019).

Despite these efforts, there are still challenges to achieving climate resilience in housing. One of the main challenges is the lack of funding and resources for implementing resilience measures in affordable housing. Another challenge is the difficulty of balancing the need for resilience with the cost of implementing measures, which can be particularly challenging for low-income households.

Numerous studies have documented the risks associated with climate change and affordable housing. For instance, a study by the U.S. Department of Housing and Urban Development (HUD) found that affordable housing is disproportionately located in areas that are susceptible to natural disasters, such as floods, hurricanes, and wildfires (HUD, 2021). Another study conducted in the United Kingdom found that climate change will exacerbate existing inequalities in access to affordable housing and increase the risks of displacement and homelessness (Anderson et al., 2022).

This study aims to address these intertwined challenges by examining the nexus between climate change and affordable housing. Through a synthesis of interdisciplinary research, case studies, and expert insights, the study aims to provide a comprehensive understanding of the multifaceted problem at hand and propose innovative strategies for tackling this dual crisis. Figure 1 has been complied based on the various aspects of climate change discussed in Section 1.

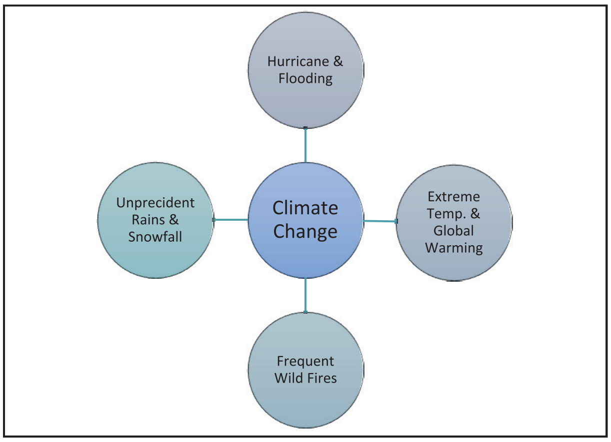


Figure 1 Climate Change.

2. CLIMATE CHANGE AND CHALLENGES TO HOUSING

Climate change has become an undeniable reality, with its far-reaching consequences already being felt in various corners of the world. The built environment is particularly vulnerable to these impacts, as rising temperatures, extreme weather events, and sea-level rise threaten the integrity and longevity of housing infrastructure. At the same time, the need for affordable housing has never been more pressing, with millions of people struggling to secure safe and dignified shelter amidst escalating economic disparities.

The impacts of climate change on housing and human settlements have become increasingly apparent, emphasizing the urgency for adaptive strategies in housing policy and infrastructure development. Climate change presents multifaceted challenges, including rising global temperatures, intensified extreme weather events, sea-level rise, and shifting precipitation patterns. These phenomena have profound implications for the built environment, particularly housing systems and the communities that rely on them. Many studies have been steered in recent years to highlight the various effects of climate change on human settlements and their habitats.

The study by Adger et al. (2021) offers a comprehensive review of climate change's effects on housing and human settlements. The study presented two strong and comprehensive reasons describing the relationship between climate change and housing calamity. Firstly, climate change exacerbates the vulnerability of housing structures to extreme weather events such as hurricanes, floods, heat waves, and wildfires. As the frequency and severity of these events escalate, the physical integrity and resilience of housing infrastructure are put to the test. This not only threatens the safety and well-being of inhabitants but also places significant financial strain on homeowners, renters, and governments tasked with repairing or rebuilding damaged properties. Secondly, climate change poses challenges to housing accessibility and affordability. Rising sea levels and recurrent flooding can render coastal areas uninhabitable or unsuitable for development, leading to a reduction in available land for housing. Concurrently, these phenomena may also drive-up insurance premiums and maintenance costs, making housing less affordable for a growing segment of the population (Adger et al., 2021).

Various studies have thrown light on the psychological toll of climate change-related disasters, such as flooding, on communities. An analysis of populations affected by flooding incidents reveals a significant association with mental health outcomes, often surpassing the physical health impacts. Rates of Common Mental Disorders

(CMDs), which encompass conditions like depression and anxiety, have been observed to rise among individuals who have experienced flooding in their homes (Butler et al., 2016; Paranjothy et al., 2007; Tunstall et al., 2006; Convery and Bailey. 2008; Tempest et al., 2017; Milojevic et al., 2017; Fewtrell and Kay 2008).

These studies highlight the profound psychological distress that such climate-related disasters can induce. The traumatic experience of seeing one's home inundated, coupled with the uncertainty and dislocation that follows, can precipitate or exacerbate mental health disorders. Such findings underscore the necessity for a comprehensive response to climate change that not only addresses the physical and infrastructural damage but also acknowledges and tackles the significant mental health burdens that these events may impose on affected populations. Thus, in the face of climate change, our resilience strategies must be holistic, incorporating mental health support alongside other essential elements.

In their comprehensive analysis, Buchanan et al. (2020) examine the impact of floods on housing structures, emphasizing the need for adequate planning, and building materials to minimize damage. The authors highlight the consequences of these events on the foundation, walls, and overall structural integrity of the affected buildings, providing valuable insights for builders, policymakers, and homeowners (Buchanan et al., 2020).

The adverse impacts of flooding on housing are multifaceted and significant, as noted by Allstate Insurance. Such impacts range from structural damage to electrical hazards and biological concerns. Structurally, floodwaters can cause a multitude of defects within a house. This includes weakened or buckling floors and roofs, as well as the development of cracks within walls and foundations. The integrity of the house's structure can be severely compromised, leading to potential risks for the inhabitants (Alstate 2023). The study further added that electrical systems within the home are also at risk during flooding. Floodwater can cause electrical wires to break or fray, posing a serious risk of electrocution or fire. Furthermore, household appliances such as heating, ventilation, and air conditioning systems, water heaters, and refrigerators may become damaged or dysfunctional because of being submerged in floodwater. This not only leads to the loss of essential home appliances but also presents additional safety hazards.

Moreover, floods can instigate biological threats within the home, specifically in the form of mold growth. Moisture-laden environments post-flooding provide the ideal conditions for mold to thrive. Within a short span of 24 to 48 hours, mold can start to grow on any damp surface. This implicates not only building materials like drywall, flooring, and insulation but also personal belongings such as clothing and furniture. The presence of mold can further exacerbate the damage caused by the flood, and also poses serious health risks to those living within the home (Alstate, 2023).

The study by Eves (2004) provides an in-depth analysis of the different causes of housing defects due to floods. The author investigates various factors, including construction materials, building age, and local topography, to determine their influence on the vulnerability of residential structures to flood damage (Eves, 2004). Whereas Paulik et al. (2021) offer an extensive review of the link between climate change, increased flooding events, and the resulting damage to housing structures. The authors highlight potential mitigation measures, such as improving building codes and flood-resistant designs, to address the challenges faced by homeowners and communities (Paulik et al., 2021).

Besides far-reaching implications of climate change extend beyond built environment concerns, as it poses significant health and safety risks, along with a myriad of economic and social impacts. As communities worldwide grapple with these challenges, it is crucial to portray the complex impacts of an increasingly unpredictable climate. In this context, a study by Mirza (2003) examines the socio-economic consequences of housing defects caused by floods, including displacement, financial burdens, and health impacts. The author emphasizes the need for comprehensive policy interventions to minimize the adverse effects of flood-related housing defects on affected communities. However, Sanjit et al. (2017) present a longitudinal study exploring the relationship between climate change, social vulnerability, and long-term social outcomes. The authors argue that addressing climate change in the region of study caused damage to fragile ecosystems and socio-economics of the eastern Himalayas and these phenomena are causing net negative effects and could be interpreted as an alarming situation in the region.

Climate change causes various traumas to communities and people. Studies examine the health implications of housing defects resulting from floods, including increased risks of respiratory issues, allergies, and mental health problems (Azuma et al., 2014; Lowe et al., 2013). The authors highlight the importance of timely and effective remediation measures to protect public health. Financial losses under climate change and recovery are major challenges being faced by people in affected areas. Besides, Amini & Memari (2020) discuss the challenges associated with insuring properties vulnerable to flood-induced housing defects. The authors propose potential solutions, such as public-private partnerships and risk-based pricing, to ensure adequate insurance coverage for affected homeowners.

Besides the provision of indemnity cover against the possible effect of climate change, Peacock et al. (2018) has compared different approaches to post-flood housing recovery, examining the effectiveness of various strategies in addressing flood-related housing defects. The authors highlight the importance of community involvement and tailored recovery efforts to meet the specific needs of affected populations.

Properties in regions severely affected by climate change experience a sharp decline in value, leading to psychological distress and overwhelming financial burdens (Mostafiz et al., 2021; Brody et al. 2007). These studies analyze the influence of flood-associated structural damage on property worth, revealing substantial reductions in market prices consequently. The researchers emphasize the importance of implementing efficient flood risk control and housing durability strategies to alleviate these economic repercussions.

Dwellings situated in climate-impacted areas frequently face the financial strains of recovery and restoration expenses. Such challenges impose a heavy load on residents, resulting in long-lasting financial obligations and the burden of repaying loans (Eid & El-Adaway, 2019; Wahab & Kasim, 2023). These studies present a cost-benefit analysis of flood-resilient housing retrofits, which can help to minimize the consequences of flood-induced housing defects. The authors advocate for targeted investments in retrofitting programs as a cost-effective solution to reduce flood risks and promote housing resilience.

Discussion under this section provides an overview of the multifaceted consequences of housing defects resulting from floods, including physical damage, health and safety risks, and economic and social impacts, as shown in Figure 2. Physical damage encompasses structural deterioration, compromised building integrity, and water damage to the interior and exterior of residential properties. This damage necessitates costly repairs and can render homes uninhabitable, forcing residents to find alternative shelter. Health and safety risks associated with flood-induced housing defects are significant, as they can lead to mold growth, poor indoor air quality, and contaminated water supplies. These conditions heighten the likelihood of respiratory illnesses, allergies, and other health complications, particularly for vulnerable populations, such as children and the elderly.

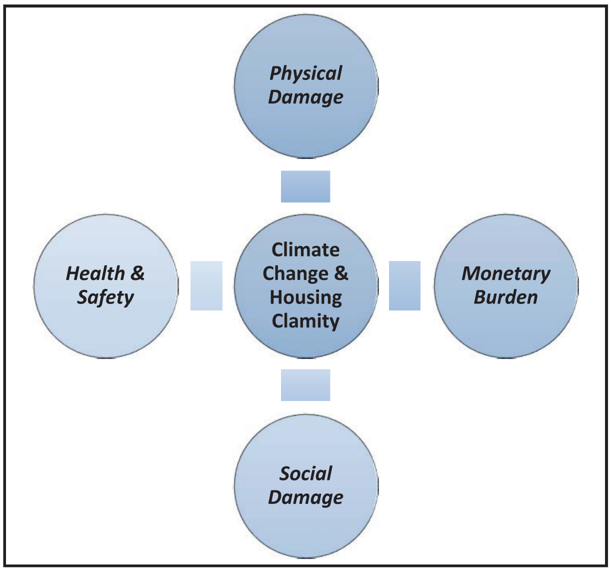


Figure 2 Implications of Climate Change.

The economic impacts of flood-related housing defects are considerable, as they can decrease property values, increase insurance premiums, and strain financial resources due to repair and relocation costs. This burden disproportionately affects low-income households, exacerbating existing inequalities. Whereas social impacts of housing defects caused by floods are diverse, ranging from displacement and homelessness to the disruption of community networks and the strain on local resources. Additionally, the psychological toll of losing one's home and the prolonged recovery process can lead to increased stress and mental health issues.

5. RESEARCH VALIDITY

In light of the escalating global apprehension regarding climate change and its potential repercussions on human habitats, this research addresses the growing need for resilient and sustainable housing systems. The mounting prevalence and severity of extreme weather occurrences, in conjunction with amplified global temperatures, unprecedented rainfall, ascending sea levels, and shifting precipitation trends, present formidable obstacles to housing infrastructure design, construction, and management. Consequently, it is imperative to explore an array of strategies and solutions that facilitate the development of housing systems adaptable to these climate-related challenges. To tackle climate change-related obstacles, this study will concentrate on establishing a robust theoretical foundation by conducting a comprehensive literature review and drawing upon concepts from disciplines such as architecture, urban planning, and environmental science. This approach ensures that the proposed solutions are rooted in a thorough understanding of the fundamental principles governing the interplay between climate change and the built environment.

5. AIM & OBJECTIVES

Based on the discussion above and participation at various sites this study proposed to investigate the interplay between climate change and the housing crisis and to develop evidence-based recommendations for policy and practice that promote resilient and sustainable housing systems. Whereas set the following objectives to achieve the study goal.

a) Conduct a comprehensive literature review and theoretical synthesis to establish a robust understanding of the existing knowledge on the relationship between climate change and housing defects and loss crisis, drawing upon relevant theories and concepts from various disciplines.

b) Conduct multiple case studies representing diverse geographical regions, climatic conditions, and housing systems to gain insights into the effectiveness of climate-adaptive strategies and to identify best practices in addressing the housing crisis in the context of climate change.

c) Perform a comparative analysis of the selected case studies to distinguish common failure patterns, contextual factors, and critical success factors that contribute to the resilience and sustainability of housing systems in the face of climate change.

d) Develop evidence-based policy recommendations and practical guidelines that promote the creation of resilient and sustainable housing systems capable of adapting to the challenges posed by climate change and addressing the housing crisis.

e) Identify areas for future research to advance knowledge on the complex interactions between climate change and the housing crisis, and to facilitate the development of innovative and effective adaptation strategies.

6. METHODOLOGY

The study involved a systematic literature review across disciplines such as architecture, urban planning, and environmental science, developing a theoretical framework aligned with the study's objectives. Data collection combined primary sources (case studies) and secondary data (literature reviews) from climate datasets, housing market statistics, government reports, and expert interviews, ensuring a multidisciplinary perspective with contributions from engineering, sociology, economics, and public policy.

Focusing on Pakistan, the research selected case studies from various flood-affected regions to analyse housing failures, the effectiveness of climate adaptation strategies, and best practices, supported by references from (Baloch 2022; Mir 2022; Rannard 2022). A comparative analysis across these cases identified common patterns and critical factors influencing the success or failure of adaptation measures.

The study's findings were validated through comparative analysis, assessing their alignment with other studies and the potential applicability of successful strategies in different contexts. Research outcomes included policy recommendations for resilient and sustainable housing adaptable to climate change and highlighted areas for further research to deepen understanding and innovate in the intersection of climate change and housing. This approach aimed to provide reliable, actionable insights for policy and practical solutions to climate-related challenges in housing, as illustrated in Figure 3.

6.1 METHODS OF MULTIPLE CASE STUDIES

To comprehensively investigate the nexus between climate change (flooding) and housing, this study proposes a methodological framework that combines theoretical and empirical evidence, embraces cross-disciplinary perspectives, and emphasizes replicability

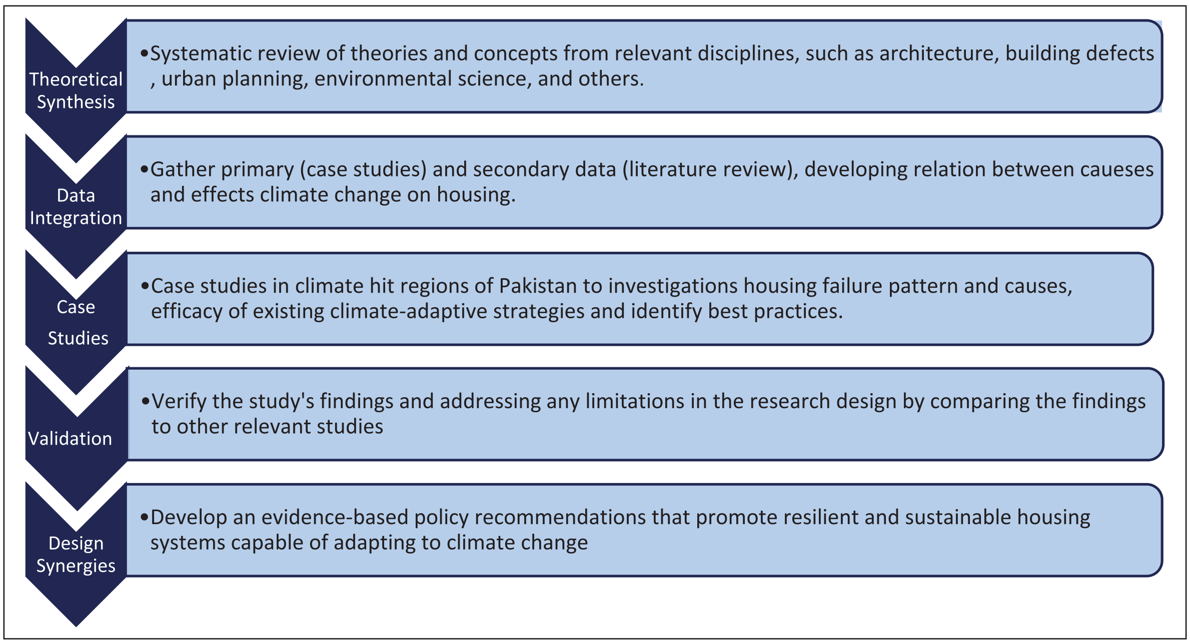


Figure 3 Methodical Flow.

and generalizability. The following outline details the key components of this methodology. In conducting multiple case studies in the flood-affected northern and southern regions of Pakistan, a comprehensive field research methodology was employed to analyze the impact of flooding on housing structures. This involved a systematic approach to data collection, encompassing site visits, qualitative interviews, and comparative analysis.

Each case study entailed a meticulous site visit to specific locations severely impacted by flooding and subsequent wash-away effects. These immediate on-site inspections post-flood events were crucial for examining the failure patterns and underlying causes of housing damage. The primary focus was on identifying structural vulnerabilities and patterns of destruction in residential buildings, providing insights into the resilience of different construction methods and materials against such natural calamities.

Interviews played a pivotal role in enriching the study. Detailed discussions with local residents and regional supporters, as acknowledged in the research, facilitated a deeper understanding of the flood's impact. These interactions provided valuable firsthand accounts and original photographs, offering a narrative perspective to the physical data gathered.

As an architect and researcher, the principal investigator conducted a comparative analysis across various cases. This involved a close condition survey of the affected buildings and houses, systematically documenting the extent of damage and identifying commonalities and discrepancies in construction practices and their performance during the flood. This methodological triangulation, combining on-site observations, stakeholder interviews, and comparative analysis, enabled a holistic understanding of the housing challenges in flood-prone areas, contributing significantly to the field of disaster-resilient architecture and regional planning.

7. RESEARCH MATRIX

The following research matrix as shown in (Table 1) provides a structured approach to investigating the interplay between climate change and the housing crisis, focusing on climate-adaptive design strategies, best practices, and generalizability recommendations:

By employing this research matrix, the study aims to systematically examine the complex relationship between climate change and the housing crisis, evaluate the effectiveness of climate-adaptive design strategies, and generate actionable insights to inform the development of resilient and sustainable housing systems.

8. CASE STUDIES-HOT SPOTS OF CLIMATE CHANGE (FLOODING) AND HOUSING DISASTER IN PAKISTAN

To accomplish the study objectives, this study considers the climate change hot spots in Pakistan and investigates the interplay of climate change, destruction pattern, and extent of destruction to build environment, particularly housing. Discussion in section 1 of this study has established that climate change has increasingly become a critical global issue, with its consequences being felt in various regions around the world. One such example is the devastating floods in Pakistan, which have led to

RESEARCH COMPONENTS	*DATA SOURCES*	*ANALYTICAL METHODS*	*EXPECTED OUTCOMES*
Climate change and the housing crisis	Literature review, governmental reports, climate datasets, housing market statistics	Content analysis, descriptive statistics, trend analysis	Comprehensive understanding of the relationship between climate change and the housing crisis, identification of key challenges and opportunities
Generalizability	Research findings, literature review, expert opinions	Synthesis of research outcomes, validation, and transferability assessment	Evidence-based policy recommendations and practical guidelines, assessment of their applicability to different contexts, identification of areas for future research
Climate-adaptive design strategies	Literature review, case studies, expert interviews, architectural and urban planning documents	Content analysis, comparative case study analysis	Identification and analysis of climate-adaptive design strategies, evaluation of their effectiveness in addressing the housing crisis
Best Practices in addressing the housing crisis	Case studies, expert interviews, governmental reports, project evaluations	Comparative case study analysis, content analysis	Identification of best practices for promoting climate resilient and sustainable housing systems, insights into factors contributing to their success.

Table 1 Research Matrix.

extensive housing destruction and affected millions of lives. The ramifications of climate change are particularly evident in the worst-hit districts of Dadu in Sindh, Swat in Khyber Pakhtunkhwa (KPK), and Pashin in Baluchistan.

It has been established by studies (Baloch 2022; Renanrd 2022; UNDP 2022;) that in recent years, climate change has been a significant driver of the increased frequency and intensity of floods in Pakistan. The country's vulnerability to floods is a direct result of the changing weather patterns, extreme temperatures, and the subsequent melting of glaciers. This has amplified the severity of natural disasters, leading to the widespread destruction of housing and infrastructure across various regions. Several studies (UNICEF 2022; Sajid 2022; Worldbank 2022) reported that climate change and resulting flooding have devastated Pakistan across the length of the country and adversely affect the communities in Sindh, Baluchistan, and Khyber Pakhtoon Khwa (KPK) provinces. The studies comprise details of the Sindh province, particularly the Dadu district, which has witnessed catastrophic flooding that has caused significant damage to homes and livelihoods. The severity of the situation has been exacerbated by inadequate infrastructure and insufficient government support, leaving the residents of the Dadu district in a precarious state. Consequently, the region faces an urgent need for rehabilitation and reconstruction efforts to mitigate the adverse effects of climate change on the local population.

Similarly, (UNICEF 2022; Sajid 2022; World bank 2022) reported that the Swat district in Khyber Pakhtunkhwa has been severely affected by climate change-induced floods. The increased rainfall and glacial melt have led to frequent flash floods, causing extensive damage to housing structures in the region. This has resulted in displacement and economic distress among the residents, necessitating immediate attention and intervention from both national and international agencies.

Whereas, in Baluchistan, the Pashin district has experienced its share of flood-related destruction, attributable to the pervasive effects of climate change. The region's susceptibility to floods, in conjunction with inadequate preparedness and response mechanisms, has led to severe housing destruction and the displacement of thousands of individuals. This scenario highlights the urgent need for sustainable solutions and measures to combat the mounting challenges posed by climate change.

In light of the credible evidence presented in the aforementioned discussion, this study has identified three areas within the most severely affected provinces of Pakistan, namely Sindh, Baluchistan, and Khyber Pakhtunkhwa (KPK). The research encompasses case studies conducted in three specific locations: Dadu in Sindh, Pishin in Baluchistan, and Swat in KPK, to examine the intricate relationship between climate change, flooding events, and housing devastation in these regions.

As per the findings of Gul (2022), at one stage, floodwaters inundated a third of the nation, resulting in the destruction or displacement of over 2 million houses, the death of 1.2 million livestock animals, and damage to 13,000 kilometers of roadways. Moreover, 8 million individuals were forced to relocate, with 644,000 seeking refuge in emergency camps. The report also indicates that the situation continues to evolve, as standing floodwaters in numerous locations contribute to the spread of waterborne and vector-borne illnesses. Consequently, over 8 million displaced individuals now face a burgeoning health crisis. The study emphasizes that the Sindh province bore the highest percentage of the brunt of the floods, accounting for nearly 70% of total damages and losses, followed by the provinces of Balochistan, Khyber Pakhtunkhwa, and Punjab. The most impoverished and vulnerable districts are particularly affected by the loss of household income and assets, escalating food costs, and the outbreak of diseases.

The districts of Dadu, Swat, and Pishin in Pakistan serve as prime examples of the disastrous consequences' climate change can have on susceptible populations. Consequently, it is crucial to emphasize devising adaptive approaches and fostering resilient infrastructure to alleviate the impacts of climate change, ultimately protecting the welfare and livelihoods of the affected communities.

In the subsequent segment of this study, each chosen location will be examined in detail to comprehend the origins of flooding and the ensuing impacts on housing and other aspects of the built environment. To facilitate an in-depth investigation of the selected sites, the authors conducted site visits to scrutinize the diverse manifestations of destruction. They also engaged in unstructured interviews, documented the patterns of damage to building structures, and investigated the traditional methods of construction and materials employed in the construction of housing across various locales.

8.1 DISTRICT DADU SINDH PAKISTAN.

The establishment of Dadu district occurred in 1933 when the British Indian administration combined Kotri and Kohistan tehsils from the Karachi district with Mehar, Khairpur Nathan Shah, Dadu, Juhi, and Shewan tehsils from the Larkana district. Located in the southern part of Sindh province and bordering Baluchistan, Dadu district boasts a rich history and is regarded as the birthplace of ancient civilizations, as shown in Picture 1. The district is situated in one hottest part of Pakistan, in summer mercury touch 52ºC. The district's residents are predominantly involved in agriculture, and geographically, the area is situated on the left bank of the Indus River. The district features expansive agricultural lands, a

Picture 1 Dadu District Sindh. Source: (wikipedia.org).

Picture 2 Building Flood Barriers in Dadu.

Picture 2a Flooding & Road Breeching.

mountainous region in the south, and one of the largest natural freshwater reservoirs, known as "Manchar Lake". In 2022, the district faced the brunt of climate change, enduring significant losses in housing, health facilities, crops, livestock, and human lives (Wikipedia.org/Dadu).

Shahzad (2022) states that unprecedented monsoons and glacial melt in Pakistan's northern region have affected 33 million people and resulted in at least 1,391 deaths, leading to the devastation of homes, roads, railways, livestock, and crops. The Indus Highway in Dadu district has experienced submersion in at least three locations, disrupting traffic for weeks, while another highway connecting the north and south of the country has also suffered significant damage due to the floods, shown in Pictures (2 & 2a) the heavy flooding, breeching of main road and magnitude of stagnant water and loss of crops.

Additional studies by Hassan (2022) and Khushik & Shahid (2022) reveal that the southern province of Sindh has experienced rainfall 466% above average levels. Dadu district's location, which is home to 1.5 million people, means that all floodwaters pass through it. With 90% of the district submerged, more than 1,200 health facilities have been inundated, leading to the spread of dysentery, diarrhea, malaria, skin diseases, and dengue fever. In total, 600 villages within the Dadu district have been submerged, leaving many residents stranded due to a lack of boats. Approximately 30,000 houses have been impacted by the floods and rain, either being destroyed or partially damaged, as shown in Picture 3 people preparing earthbags to mend breech to stop the inflow of flooding water.

8.1.1 House Design and Construction

Adhering to time-tested design and construction principles, courtyard houses in Dadu epitomize a classic architectural approach. In this hot, improvised region, homes are typically designed with a centralized courtyard encircled by rooms and service areas,

Picture 3 Mending Breech.

fostering a sense of community and promoting natural ventilation. The construction process employs a hybrid model, combining both adobe materials (such as clay, bricks, husk, jute, trunks, cattail thatch "chikh" and limestone) and industrial materials (like cement, concrete, I and T sections steel and rebar bars), as shown in a partially destroyed house in Pictures 4 & 5. Sturdy, sustainable load-bearing walls are crafted using baked and sun-dried bricks. To ensure a solid roof structure, – section and T-section iron girders or wooden trunks are incorporated with brick tiles, known as "choka".

Bricks are laid using mud and jute mortar, mud and husk mortar, or cement mortar, resulting in a secure bonding and improved durability. The courtyard house design stands as a testament to the efficiency and lasting allure of traditional construction methods.

8.1.2 Pattern of Design Failure

Upon conducting site visits and surveys of numerous houses and buildings in the Dadu district, a harrowing depiction of destruction and design failure becomes

Picture 4 Rain & Flood Damage.

Picture 5 Submerge roads and houses in flood water.

evident, as shown in Pictures 6 and 7. The extent of the damage demonstrates the vulnerability of both the people and their built environment to the impacts of climate change. These observations underscore the urgent need for architects, engineers, and policymakers to address the current shortcomings in building design and construction practices. By doing so, they can help develop resilient infrastructure and adaptive strategies to protect communities from the adverse effects of climate change, ensuring their safety and well-being in the face of this growing global challenge.

Picture 6 Damaged Courtyard House.

Picture 7 Heavy Rains Collapsed Masonry Dome.

The impact of climate change on architecture is evident in the courtyard house design, as it exposes the vulnerability of low-resilient materials and construction methods. The consequences of climate change-induced failures include the loss of bonding in walls, the appearance of deep diagonal cracks in the wall system, and the opening of joints at wall corners. Additionally, soil erosion has led to the failure of structural elements, while water ponding on roofs and the deterioration of adobe materials further weakens the structure. Inadequate land levelling can impede surface water drainage, exacerbating soil erosion and potentially damaging the foundation. Furthermore, a high-water table has resulted in dampness, causing floor failures. To mitigate these issues, it is essential to adapt resilient architectural designs and construction techniques to the challenges posed by climate change. Addressing these design flaws is crucial to ensure the longevity and stability of a building.

8.2 DISTRICT SWAT, KPK

Khyber Pakhtunkhwa is characterized by diverse topography, encompassing mountain ranges, scenic beauty, vast forests, rolling submontane areas, and plains encircled by hills. The rugged basins of the Panjkora, Swat, and Kandia rivers are located south of the Hindu Raj, as shown in Picture 8. The region, including the Swat district, is positioned within an earthquake-prone area, causing frequent mild tremors. A substantial portion of Swat's population is engaged in the tourism sector, which accounts for nearly 37% of the district's economy. Other industries contributing to the economy include agriculture, forestry, handicrafts, mining, and gemstones. Due to climate change, Swat experienced unprecedented rainfall, floods, and landslides during the 2022 monsoon season, resulting in severe damage (wikipedia.org/Swat).

Ashfaq (2022) cites the Provincial Disaster Management Authority (PDMA), reporting that torrential rains and floods destroyed 35,123 houses and partial damage to 52,327 others throughout the KPK province. The report also states that floods and heavy rainfall claimed the lives of 289 individuals, including 139 men, 109 children, and 41 women. Among the injured were 139 men, 130 children, and 79 women, with the Swat district accounting for 34 fatalities.

In a separate report, Ali (2022) highlights the flood's impact on educational and health facilities, as well as infrastructure. The floods destroyed 90 schools and damaged an additional 1,096 in the province. Furthermore, 91 health facilities experienced damage, including 52 basic health units and 37 dispensaries. The natural disaster also compromised over 1,455 kilometers of roads and 73 bridges, predominantly in Swat (29). Additionally, 76,700 houses in KPK sustained damage, as shown in Picture 9.

8.2.1 House Design and Construction

Being a prosperous and hilly tourist region, the design of housing and other built forms (hotels) in the Swat district is particularly different from the design parameters mentioned in section 8.1.1 of this study. Site visits were limited to hotel and standalone private residences. In the scenic Swat district, contemporary hotel designs harmoniously merge aesthetics, functionality, and memorable guest experiences. These modern establishments feature welcoming lobbies and viewing balconies, providing spaces for relaxation

Picture 8 District Swat in KPK. Source: (wikipedia.org).

Picture 9 District Swat Floods & Submerged Bridge.

and socializing while showcasing the region's awe-inspiring natural surroundings. Thoughtfully designed guest rooms with en-suite bathrooms and toilets ensure a comfortable and convenient stay. Rooms and other facilities are vertically arranged in multi-story structures, optimizing the use of available space. Reinforced concrete construction (RCC) is employed extensively (Pictures 10 & 11) offering durability and structural integrity while incorporating innovative building services such as energy-efficient HVAC systems, advanced communication networks, and state-of-the-art security features. However, the adverse effects of climate change and heavy rains have led to the partial or complete collapse of some hotels in the area. This highlights the need for more robust, climate-resilient designs and infrastructure that can withstand the challenges posed by an ever-changing environment.

However, house designs in the Swat district are deeply rooted in local traditions and mindful of cultural and religious sensitivities. The classic courtyard house layout is a popular choice, striking a balance between privacy, social interaction, and climatic considerations. With south-facing orientations, these homes maximize solar gain, ensuring adequate warmth and sunlight throughout the year. The centralized courtyard, surrounded by rooms and service areas, serves as a focal point for daily activities and family gatherings. Construction methods include both reinforced concrete (RCC) and load-bearing wall systems, catering to the region's specific needs and preferences as shown in Pictures (10, 11 & 12). Walls are typically built using stone or cement block masonry, reflecting the area's rich architectural heritage and locally available materials. Roofs are designed using either RCC or I and T section steel framing, topped with precast RCC slabs for enhanced durability and weather resistance. These thoughtful design features embody the essence of Swat's unique architectural legacy while addressing modern-day requirements for comfortable and sustainable living.

8.2.2 Pattern of Design Failure

In contrast to the destruction outlined in section 8.1.2 of this study, the design failures in the Swat district can be attributed to various factors, including policy shortcomings, inadequate building control measures, and environmental challenges. Overflowing rivers and streams due to heavy and persistent rainfall exacerbated the destructive force of high-velocity riverine water, causing widespread soil erosion and landslides. This, in turn, led to the washing away of subsoil and structural elements, buckling in reinforced concrete components, and sagging in flooring systems, ultimately resulting in a partial or total collapse of buildings, as shown in Pictures (12, 13).

Low-rise hotels situated within the river's catchment area were particularly vulnerable to these disastrous events. The failure to respect natural water channels and the encroachment on rainwater routes further intensified the damage inflicted on the built environment, as shown in Pictures 10 & 11. The lack of comprehensive environmental studies for housing developments, coupled with an apparent disregard for the importance of such assessments, has also contributed to the design failures witnessed in the Swat district. These unfortunate circumstances highlight the urgent need for more rigorous policy implementation, effective building control

Picture 10 RCC Construction & Leftovers of Flood 1.

Picture 11 RCC Construction in River Catchment.

Picture 12 Damage to Housing by Heavy Rains.

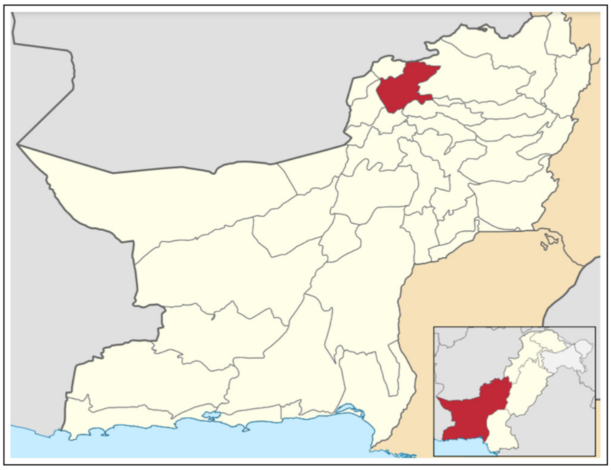
Picture 13 Damage to House in Landslide**.**

measures, and greater consideration of environmental factors to minimize the risk of future design failures in the region.

8.3 DISTRICT PISHIN BALUCHISTAN

Pishin District is situated in Baluchistan, the largest province of Pakistan. Established in 1975, the district was formed by separating from the provincial capital, Quetta. Pishin District lies to the north of Quetta City, bordered by Afghanistan to the northeast and Killa Saifullah to the east, as shown in Picture 14. The district consists of a series of valleys, with ground elevations ranging from 1,370 to 1,680 meters above sea level. The Lora River and its tributaries, which meander through Pishin, serve as major water sources. Pishin District has been a flood hotspot, suffering significant consequences from such events (wikipedia.org/Quetta Division).

During the monsoon season (June to August 2022), Pakistan experienced unprecedented devastation caused by relentless rainfall and subsequent flash floods. The continuous and extended downpour of monsoon rains primarily impacted the provinces of



Picture 14 Pishin Baluchistan. Source: (wikipedia.org).

Picture 15 Total Collapse of Estate.

Picture 16 Loss of Power Grid.

Picture 17 House Loss & Displaced People.

Baluchistan, Sindh, and Khyber Pakhtunkhwa from mid-June to the end of August 2022. Baluchistan was subject to the most severe rainfall, resulting in the loss of 244 lives, vast amounts of mud-debris, and significant effects on approximately 430,416 people. The collapse of seven dams further intensified the tragic circumstances. Thousands of families were displaced (Picture 17) and subjected to harsh weather conditions (OCHA 2022; Nazir 2022). The studies further revealed that the floods inflicted extensive damage across various sectors, including roads, schools, railway tracks, water reservoirs (dams), drinking water sources, bridges, electricity, agriculture, horticulture, livestock, shops, markets, and communication networks, as shown in (Picture 16) .

The report further mentioned that widespread flooding in numerous districts across Baluchistan, Sindh, and Punjab provinces led to the destruction of vast tracts of agricultural land. The country could soon confront food shortages if the affected cropland remains unrestored. In Baluchistan, more than 25,000 houses were damaged by floods and heavy rains, while approximately 2,000 houses in the Pishin district either collapsed or suffered partial damage.

8.3.1 House Design and Construction

In the Pishin district, house designs are adapted to the improvised region by employing low-resilience materials and sustainable construction practices that align with the local culture, privacy, and religious sensitivities. Traditional courtyard houses are prevalent, featuring high boundary walls constructed from thick sun-dried husk & mud blocks to ensure privacy. South-facing orientations are favored for optimal solar gain, with a centralized courtyard bordered by rooms and service areas to create a harmonious living environment.

Load-bearing wall construction is employed, utilizing thick clay or brick masonry walls to provide both insulation and structural support. Roofing options include either reinforced concrete or I and T section steel frames with precast concrete slabs, as well as date palm thatch covers supported by cylindrical wooden trunks. The latter option is finished with a rammed clay mortar applied to the top surface for added protection. For the construction of the walls, bricks are laid in either mud and husk mortar or a cement and sand mixture, ensuring minimal durability and stability. These design principles reflect a deep understanding of the local context and the need for environmentally conscious, culturally sensitive, and resilient housing solutions in the Pishin district.

8.3.2 Pattern of Design Failure

Located in a dry and hilly area, the Pishin district shares some geographical similarities with Swat (KPK) and experiences similar material failures as those reported in Dadu (Sindh). This study identifies design failures in the Pishin region, encompassing findings outlined in sections 8.1.3 and 8.2.3.

It has been observed that the repercussions of climate change-driven failures encompass compromised wall bonding, the emergence of significant diagonal wall cracks, and the separation of joints at wall corners. Furthermore, wash away effects and soil erosion contributed to the breakdown of structural components, while water accumulation on rooftops and the degradation of adobe materials weakens structures, as shown in Picture 18. Whereas low-lying housing site and poor land levelling hinders surface water drainage, intensifying soil erosion and potentially causing foundation damage, as shown in Picture 19.

In addition to these factors, the hilly terrain of the Pishin district exposes it to climate change policy deficiencies, insufficient building control measures, and environmental obstacles. Persistent and heavy rainfall leads to overflowing and inundated natural water channels and streams, magnifying the destructive force of high-velocity surface water. This results in widespread soil erosion and landslides, which in turn wash away subsoil and structural elements, cause buckling in reinforced concrete components and induce sagging in flooring systems, shown in Pictures 15, 16 & 18. Collectively, these issues contribute to the partial or total collapse of buildings in the Pishin district.

9. FINDINGS OF CLIMATE CHANGE'S IMPACT ON HOUSING IN PAKISTAN

In Pakistan, climate change-induced housing loss can be primarily attributed to extraordinary rainfall and flooding events. In recent times, Earth's climate has undergone considerable changes, leading to severe impacts on both human societies and ecosystems. One of the most urgent issues emerging from these alterations is the heightened frequency and intensity of floods. In Pakistan, this development is linked to a variety of other factors such as floodplain modifications, unparalleled precipitation, embankment failures, management lapses, and breaches of existing water-sharing arrangements with neighbouring nations.

Floodplains, acting as natural extensions of rivers, play an essential role in reducing flood hazards by offering spaces for surplus water to be absorbed and dispersed. Nonetheless, anthropogenic activities like urbanization and land use shifts have caused significant changes in these indispensable ecosystems. Consequently, the inherent ability of floodplains to protect against floods has been diminished, resulting in more catastrophic outcomes during extreme weather incidents, as depicted in images (2, 9, 10, 12, 16).

In Pakistan, unparalleled rainfall driven by climate change has also become a major factor in the intensification of flood episodes. As a result, the nation

Picture 18 Structurally Damaged House.

Picture 19 Total Collapsed Adobe House.

now faces more concentrated rainfall over condensed timeframes, leading to sudden floods that surpass existing infrastructure and natural drainage capabilities. Furthermore, the erratic nature of these rainfall patterns complicates flood management tactics, as conventional prediction techniques may no longer suffice for gauging potential flood event magnitudes.

Another pivotal aspect exacerbating flood severity is the collapse of embankments designed to restrain rivers, water channels, and streams from overflowing. Various factors, including subpar construction, insufficient upkeep, and overwhelming floodwater pressure, can cause these structures to fail. Such failures bring disastrous consequences for communities and infrastructure in the affected areas, particularly in the Dadu district, as illustrated in images (2, 3).

In contrast, Section 8 demonstrates that climate change has led to the partial destruction or washing away of over 2 million homes, indicating that housing in Pakistan is highly susceptible to the adverse effects of climate change. Climate change continues to pose significant challenges in Pakistan, leading to a cascade of detrimental effects, including substantial housing loss and destruction. The escalating environmental crisis contributes to soil degradation and erosion, which, in turn, weakens the foundational integrity of residential buildings. Consequently, these structures exhibit visible signs of distress, such as cracks in walls and compromised frameworks. Moreover, the increased frequency and intensity of extreme weather events, such as heavy rainfall and flooding, exacerbate the situation by destabilizing the ground beneath the buildings. This precarious situation has given rise to widespread land sliding, causing substantial damage to both residential and commercial properties.

9.1 COMPARATIVE ANALYSIS

The aftermath of flooding in districts like Dadu and Pishin in Pakistan has shown the devastating impact of these natural disasters on housing structures, with the damage being more pronounced compared to the district of Swat. A significant correlation has been observed between the type of construction and the extent of damage. Structures built using adobe and hybrid construction methods have been affected more severely than those employing Reinforced Cement Concrete (RCC) techniques.

In the case of adobe houses, the damage ranged from wall cracks to complete structural collapse, highlighting the inadequacy of this construction approach against the relentless onslaught of floodwaters. Soil erosion was another prevalent issue, further undermining the structural integrity of these homes. Additionally, visible defects were found in the floors and roofs of these dwellings, further exacerbating the already grim situation.

In Swat district, although the extent of damage was comparatively less, significant structural issues were observed. Walls and structural systems showed signs of failure, with the foundational structures of homes experiencing notable damage. Water storage tanks were not spared either, further compounding the residents' woes. An alarming observation was the partial destruction of buildings due to landslides, a potent reminder of the destructive capacity of these natural disasters. Furthermore, the force and velocity of the floodwaters resulted in a 'wash-away' effect, causing further harm to the already compromised structures. These observations underscore the pressing need for a more robust, climate-resilient approach to housing construction in these vulnerable regions. The various types of housing defects observed by this study at three sites are being grouped in Table 2. Following evaluation rubrics has been employed to record the observational studies based on several criteria extracted for literature review:

- **Existence (*):** This criterion is likely used to confirm the presence or absence of a particular feature or characteristic at the observation site. If a characteristic exists, it's denoted with an asterisk (*). This could be a binary indicator simply noting whether a particular variable has been observed without detailing its extent or impact.
- **Frequency of Appearance (p/f):** This criterion measures how often a feature or characteristic appears within the observational study. "p" stands for "present" indicating the feature appears at least once, while "f" implies "frequent" to denote that the feature appears regularly or multiple times. This helps in understanding the consistency or regularity of the observed feature.
- **Building Type (1–2–3):** This part of the rubric refers to categorizing observed buildings into three predefined types. Each type (1, 2, or 3) could correspond to different characteristics, uses, or structural forms. For instance, '1' be Adobe construction, '2' Hybrid construction, and '3' RCC construction. This classification allows for a nuanced analysis of data based on the type of building being observed.
- **Not Available (n/a):** If information or data about a feature is not available or was not collected during the observational study, it is marked as "n/a". This indicates that the factor is not relevant or does not exist.

To effectively consolidate observational studies using this rubric, each site was assessed according to these criteria. Observers would note the existence of relevant features, record the frequency of their appearance, classify buildings as needed, and acknowledge any data limitations. By applying this systematic approach, study has gathered, compared, and analyzed data

NO	HOUSING DEFECTS	FREQUENCY (PARTIAL/FULL)	BUILDING TYPE-ADOBE[1]/ HYBRID[2]/ RCC[3] & LOCATIONS OF CASE STUDIES		
			SAWAT	DADU	PISHIN
1.	Wall collapsing	f	*2/3	*1	*1/2
2.	Cracks in wall system	p	*2/3	*2	*1/2
3.	Cracks in structural system	p	*3	*2	*2
4.	Roof collapsing	p	–	*1	*1/2
5.	Sag in roof	p	*3	–	–
6.	Soil erosion	p	*2/3	*1/2	*1/2
7.	Sag in floors	p	*2/3	–	*1/2
8.	Deformation in windows	f	*2/3	*1/2	*1/2
9.	Deformation in doors	f	*2/3	*1/2	*1/2
10.	Damage to water storage tanks (OH/UG)	f	*2/3	n/a	n/a
11.	Damage to plumbing fixtures and appliances	p	*2/3	*2	*2
12.	Damage to electrical wiring and fixtures	f	*2/3	*2	*2
13.	Biological attack	p	*3	–	–
14.	House/Building washed away	p	*3	–	*2
	Table Rubrics: (*-existence) (p/f- frequency) (1–2-3 building type) (n/a-not available)				

Table 2 Housing Defects caused by Floods.

across different sites in a structured and consistent way. This process aided in identifying patterns, drawing conclusions, and making recommendations based on the observational data collected.

Case studies and participation at various flooding-hit sites suggested that the causes of housing failures in Pakistan can be attributed to several factors: First, non-resilient design and construction practices, which result from an inadequate focus on structural strength, material selection, and workmanship, lead to housing vulnerabilities during extreme weather occurrences. Second, the absence or obsolescence of building codes left structures susceptible to damage, as they fail to consider climate change-related risks. Finally, inefficient urban planning, characterized by unchecked urban expansion and a scarcity of green areas, intensified the climate change's impact on housing and hinder community recovery in the aftermath of disasters.

Additionally, several secondary factors exacerbate the situation, such as encroachment and urbanization within floodplains, which disrupt their capacity to mitigate floods. Breaches in embankments further contribute to the problem by allowing floodwaters to inundate nearby areas. The use of low-resilience construction materials, inadequate design, and the lack of adherence to building codes all play a role in the vulnerability of structures facing these climate change-related challenges. To address these issues and safeguard housing infrastructure, it is vital to adopt comprehensive strategies that consider the various factors contributing to housing loss in the context of climate change in Pakistan, Figure 4 depicts the summary of this section 9.

Therefore policymakers, urban planners, and environmentalists must work together to develop and implement strategies that can safeguard the nation's housing infrastructure from the consequences of an ever-changing climate. This study considers that by investing in sustainable practices, adaptive construction methods, and effective disaster response mechanisms, Pakistan can ensure the safety and well-being of its citizens while also building resilience against the mounting threats of climate change-induced housing loss and destruction.

10. RESILIENT BUILDING DESIGN FOR A CHANGING CLIMATE

In the following sections, a study has explored the importance of adaptive and resilient design in creating affordable housing that can withstand the test of time and climate. The study delves into the potential of new materials, construction techniques, and sustainable technologies to reduce the environmental footprint of housing, while also making it more accessible to those in need. Furthermore, this research investigates the role of policy frameworks and community engagement in

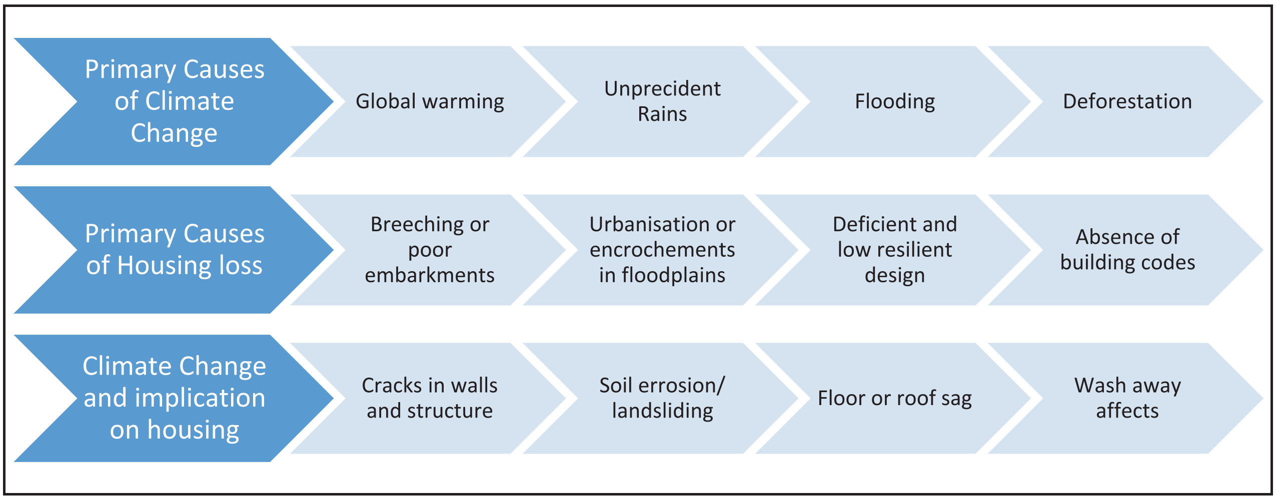


Figure 4 Causes and implications of climate change on housing in Pakistan.

promoting the adoption of climate-resilient affordable housing.

Under climate change mitigating disaster risk revolves around diminishing the destruction triggered by calamities. This encompasses steps taken to reduce vulnerability and boost the resilience and capacity of communities (Baudoin et al. 2016). Such initiatives are categorized into structural and non-structural measures. Structural measures include actions that involve the enhancement of design, the formulation and application of construction standards and guidelines, the fortification of structures susceptible to hazards, and the execution of efficient building practices (Kreibich et al. 2015). However non-structural measures include the introduction of land use planning based on potential hazards and vulnerability assessments, discouraging construction in high-risk areas, creating buffer zones, relocating settlements to safer areas, conducting public awareness programs about hazards, vulnerability, risk mitigation, and fostering disaster resilience (Adelekan 2016).

Given the high risk of damage from climate change, there is a need to improve the resilience of affordable housing to climate change. This requires a multi-faceted approach that involves policy interventions, community engagement, and technological solutions. One strategy is to invest in green infrastructure that can mitigate the effects of climate change. Green infrastructure includes measures such as green roofs, rain gardens, and trees that can help to reduce the risk of flooding and erosion while providing other benefits such as improved air quality and enhanced biodiversity (Parker and Simpson 2020; Khodadad et al. 2023; Choi et al. 2021; Ramyar et al. 2021).

An additional approach is to focus on low carbon and energy efficiency measures that can reduce the environmental impact of housing while also lowering energy bills for residents. For instance, installing energy-efficient appliances and improving insulation can help to reduce heating and cooling costs and greenhouse gas emissions, this will eventually reduce the level of global warming. (Kamal et al. 2021). Furthermore, there is a need to ensure that affordable housing is located in areas that are less vulnerable to climate change impacts. This requires a comprehensive approach that includes land-use planning, zoning regulations, and community engagement to ensure that vulnerable populations are not disproportionately impacted by climate change (Green 2014).

To address the challenges of housing in the face of climate change, a multi-faceted approach is required. Another extensive strategy is to invest in green infrastructure that can mitigate the effects of climate change. Green infrastructure includes measures such as green roofs, rain gardens, and trees that can help to reduce the risk of flooding and erosion while providing other benefits such as improved air quality and enhanced biodiversity (Parker & Zingoni 2019). Another long-term strategy is to focus on energy efficiency measures that can reduce the environmental impact of housing while also lowering energy bills for residents. For instance, installing energy-efficient appliances and improving insulation can help to reduce heating and cooling costs and greenhouse gas emissions (Kamal et al. 2021).

The above-mentioned synergies are time-consuming and extensive and the increasing frequency and intensity of floods due to climate change have necessitated the development of housing designs that can withstand these challenges in flood-prone areas. Therefore, there is an immediate need to address the sufferings of people who experienced losses in their housing. In this regard, various studies have highlighted the design solution for immediate action to prevent losses from another season of heavy rains and possible flooding. In this regard, various studies have highlighted the design solution for immediate action to prevent losses from another season of heavy rains and possible flooding.

Building houses in the cluster and raising the base of a house or lot as a whole above the floodplain level ensures that house enclosures remain dry during floods. This design strategy can employ stilts, piers, or earth mounds to elevate the structure. However, elevated homes may have higher construction costs and require additional maintenance (Shabani, Khan, & Amaratunga 2019). The use of flood-resistant materials also promotes resilience in buildings in flood-prone areas. Materials such as concrete, backed bricks, and treated wood, can minimize damage from water exposure. Furthermore, implementing waterproofing techniques for walls and floors can enhance the resilience of structures during flood events (Mitrani & Sattary 2021).

Building flood barriers (temporary or permanent barriers) around the site is considered time-tested and immediate protection from buildings and housing in low-lying areas. Such barriers can be built from sandbags or floodgates, which can help protect homes from floodwaters. These barriers can be incorporated into the landscape or architectural design of the house (Penning-Rowsell & Wilson 2015). Whereas as housing at waterfronts is highly exposed to rising water levels and sea storms and floods and cannot be braced through temporary barriers, they require special design considerations. In this case, floating homes design and amphibious architecture are considered very responsive and successful solutions. Floating homes and amphibious architecture enable structures to float temporarily during flood events, protecting rising water levels (O'Keefe & Westgate 2015).

Access to the amount of water, and overloaded city drainage during flooding season is a major problem, green infrastructure design could be a viable solution to the problem. Incorporating green infrastructure, such as rain gardens, bioswales, or permeable pavement, can help reduce stormwater runoff and alleviate flood risks in urban areas (Coutts & Hahn 2015). However, implementing these strategies is not without challenges. One challenge is the cost of implementing these measures, which can be prohibitive for low-income households. There is also a need to ensure that these interventions do not lead to gentrification or displacement of vulnerable populations (Streimikiene et al. 2020).

These innovative housing designs, coupled with proper urban planning and policy implementation, can significantly enhance the resilience of homes in flood-prone areas. The resilience of housing in the face of climate change is a critical issue that requires urgent attention. There is a need for policy interventions, community engagement, and technological solutions to improve the resilience of housing to climate change. It is crucial to ensure that vulnerable populations have access to safe and sustainable housing that can withstand the impacts of climate change. Figure 5 extracted from the discussion above depicts the pictorial understanding of issues established as synergies to fight climate change in housing.

11. RECOMMENDATIONS FOR HOUSING DESIGN SYNERGIES AND CLIMATE RESILIENCE IN PAKISTAN

Considering the obstacles outlined in Sections 8 and 9 of this study, along with the design possibilities presented in Section 10, it is crucial to incorporate climate change adaptation measures into Pakistan's housing policies and infrastructure development. This requires a strategic approach that incorporates both short-term and long-term planning measures. In the short term, immediate actions should focus on raising awareness and promoting resilience in vulnerable areas, while the long-term planning initiatives should involve developing comprehensive policy frameworks, such as climate change adaptation strategies, master planning, and climate-resilient building codes, to ensure sustainable

Figure 5 Resilient Design Initiatives.

housing and infrastructure development in the face of ongoing climate challenges, as shown in Figure 6.

11.1 LONG-TERM PLANNING FOR CLIMATE-CONSCIOUS HOUSING DESIGN

a) Encourage cooperation and the exchange of knowledge among stakeholders, including relevant design experts, users, and policymakers.

b) Evaluate trade-offs, maximize synergies, and develop housing design policies and building codes that promote climate-adaptive design approaches, such as clustered housing, elevated lot housing, raised foundations, flood-resistant materials, and energy-efficient construction technologies. These actions can improve housing resilience and decrease long-term costs related to climate-induced damage.

c) Develop and execute sustainable urban planning and land use policies, with urban planning fostering compact, mixed-use development patterns to curb urban sprawl and minimize the environmental impact of human settlements.

d) Prioritize and support investments in climate-resilient infrastructure, upgrading existing housing stock and systems (e.g., stormwater management) to better withstand climate change effects. Providing equal access to climate-resilient housing, infrastructure, and public spaces enhances social cohesion and overall community resilience.

e) Advocate for and facilitate affordable, modular, and climate-resilient housing, as well as offer financial aid and relocation assistance for those affected by climate-related displacement.

f) Maintain fairness in urban adaptation strategies and give priority to the needs of vulnerable groups, such as low-income communities, the elderly, and individuals with disabilities.

11.2 SHORT-TERM PLANNING FOR CLIMATE-CONSCIOUS HOUSING DESIGN

a) Utilize social media, local context, and language to inform people about adaptive strategies that effectively tackle the multifaceted challenges (immediate) posed by climate change, ensuring long-term resilience and sustainability of housing systems and human settlements.

b) Incorporate an economic perspective through sustainable materials, local construction, and economic growth aligned with climate resilience. This includes fostering a new green industry, job creation, aiding local businesses in adopting climate-smart practices, and investing in infrastructure that enhances economic productivity while addressing climate risks.

c) Establish a social dimension by engaging communities and enhancing their capacity, involving residents in decision-making processes, and building local capacity. This approach strengthens social cohesion, instills a sense of ownership, and improves the effectiveness of resilience initiatives.

d) Assisting local people, builders, and skilled tradesmen in learning and adapting climate

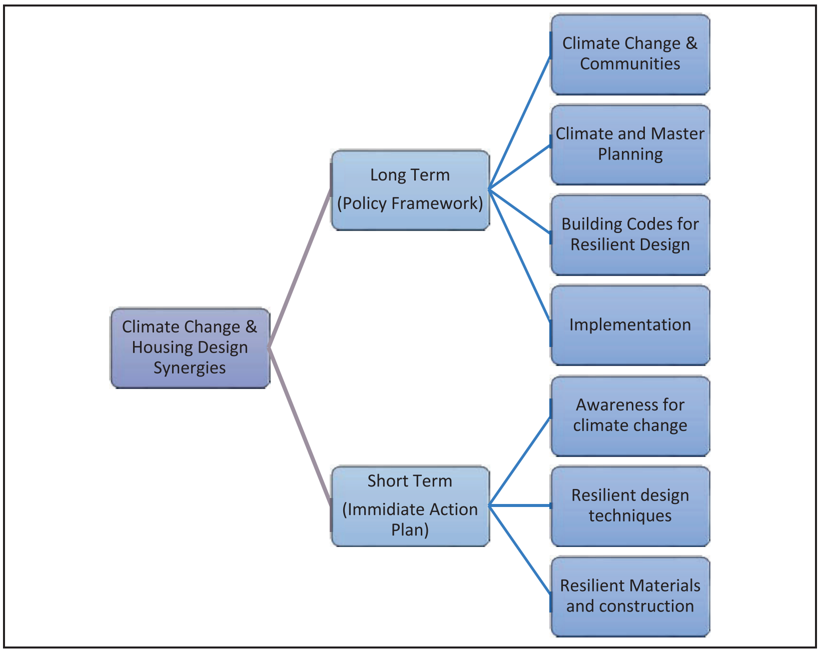


Figure 6 Climate Change & Housing Design Synergies.

resistance housing design and construction techniques and practices.

This research suggests that by carefully implementing both short-term and long-term measures, the government and citizens can create appropriate mechanisms and integrate resilience-enhancing practices to meet regional and immediate needs, as shown in Figure 7. By embracing these suggestions, holistic strategies can be developed to safeguard infrastructure, the environment, and communities from various shocks and challenges. This approach sets the stage for sustainable, resilient, and inclusive urban and rural development in an increasingly uncertain and interlinked world.

CONCLUSION

This research commenced with the premise that the challenges of housing resilience in the face of climate change are considerable and demand immediate action. Furthermore, climate change disproportionately impacts vulnerable populations, including low-income communities, the elderly, and individuals with disabilities. These groups often reside in areas more exposed to climate risks and might lack the means to adapt their housing or move to safer locations. This disparity underscores the importance of incorporating social equity in the development of adaptive housing policies and strategies.

Throughout this research, an analysis of studies by Baloch (2022), Rannard (2022), and IIPS (2022) have revealed the alarming degree to which climate change has negatively impacted Pakistan. The country has faced considerable setbacks in multiple areas, such as housing, infrastructure, agricultural production, and the loss of human lives. These findings stress the crucial need for Pakistan to implement adaptive measures and resilience-building strategies to counteract climate change's harmful consequences and safeguard its vulnerable communities, infrastructure, and natural resources for future generations.

To examine housing loss, this study conducted case studies in climate change hotspots in Pakistan, investigating prevailing house designs, construction methods, and issues of non-resilient design at the site. The research identified that housing failure primarily resulted from deficient design, the use of low-resilience materials, the absence of building codes, weakened structural integrity, vulnerability to climate-related disasters, unsuitable locations, constructing homes and other structures in high-risk areas like floodplains, a lack of awareness and preparedness, and homeowners' limited comprehension of climate change risks, which exacerbate the impacts of extreme weather events on housing. The study conducted a comprehensive analysis of flood-induced housing defects, identifying 14 significant issues affecting various types of constructions (Table 2). The housing types under investigation ranged from adobe and hybrid constructions to Reinforced Cement Concrete (RCC) structures. Each type displayed unique vulnerabilities to flooding, with defects manifesting differently across these structures.

Drawing from literature reviews in various sections of this research, this study proposed long-term and short-term initiatives to address climate change and housing design (Figure 7). In this context, multiple steps were suggested, such as investing in green infrastructure and energy efficiency measures, policy formulation, trade-offs and synergies, and the use of integrated assessment tools and frameworks by decision-makers, enabling the evaluation of multiple criteria and stakeholder perspectives. These steps will involve residents, businesses, and other stakeholders in identifying priorities, assessing potential impacts, and collaboratively developing adaptation strategies. Additionally, long-term goals include fostering partnerships among governments, the private sector, and civil society organizations, which

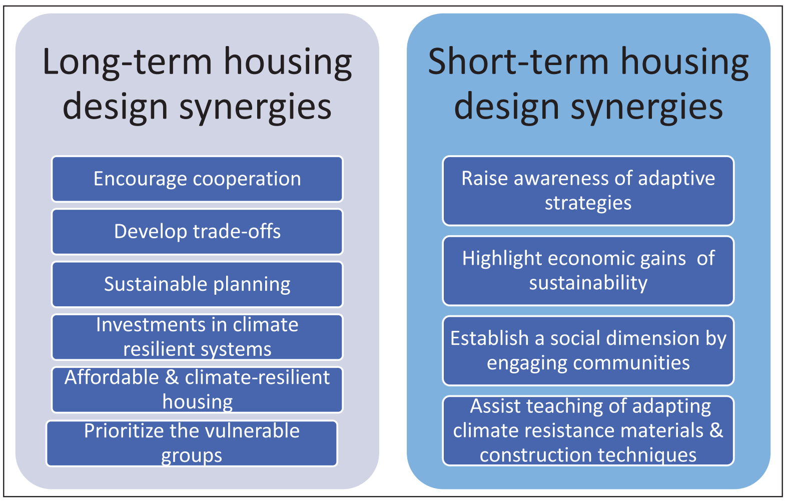


Figure 7 Long and short terms housing design synergies in climate change scenario.

can help mobilize resources, knowledge, and expertise to tackle the complex challenges presented by the housing crisis and climate change. This collaboration can expedite the development and implementation of innovative, context-specific solutions that balance social, economic, and environmental goals.

This study confined its scope to review the effects of climate change and its implications on housing in Pakistan. However, numerous other research paths are available in the context of climate change and the built environment. For instance, studies can be conducted on topics such as "Sustainable Design for Climate-Resilient Housing in Hot and Arid Climates" or "Climate Resilience and Improving Local Materials and Construction Techniques."

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

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