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Cost-Benefit Analysis of Climate-Resilient Housing in Central Vietnam

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Front cover photo: Destroyed House: The house, which is very near the coast, was completely destroyed by Typhoon Ketsana in late September 2009. Although it was made of bricks and concrete, it wasn't designed specifically with typhoons in mind, and was not strong enough to withstand a direct hit from a major typhoon like Ketsana. Houses like this one need to be rebuilt stronger to resist future typhoons.

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March, 2016

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COST-BENEFIT ANALYSIS OF CLIMATE-RESILIENT HOUSING IN CENTRAL VIETNAM

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EXECUTIVE SUMMARY

Groups vulnerable to storms and typhoons mainly belong to the poor, who usually lack basic resources for response and recovery. Due to technical failures in housing construction, a considerable amount of their income is spent on house repairs or reconstruction after annual storms. Sometimes, they fall into debt from having to borrow from other people much more money than they can afford. Without technical guidance, they unknowingly repeat the same practices, thereby reproducing risks to subsequent storms. This study applied a cost-benefit analysis (CBA) to quantify the economic benefits of long-term, safety-related measures put in place for housing. This method of analysis has proven that investing money on climate-resilient houses is essential in providing at-risk families with positive net benefits by preventing losses.

Qualitative and quantitative methods of data collection were concurrently used, and included 200 household questionnaires, 10 focus group discussions (FGD), and 15 key informant interviews (KII). Questionnaires were administered by the research team, who have experiences in survey techniques and have been involved in the piloting and drafting the questionnaire. The study area was Thua Thien Hue province, where two sites were selected for the field survey. These were Loc Vinh commune (a rural residential area of this province) and Huong So ward (an urban residential area), where people's houses, especially the poor and low income, are extremely vulnerable to storms and typhoons.

Based on the projections of two implementation options (*three-compartment house* and *tube house*) using both private and social discount rates, the research generated policy implications for each option. Each option was assessed for their appropriateness based on the results of the FGDs conducted with experts and agencies. KIIs with key persons in the field were also used to further assess the validity and applicability of the results before reaching a conclusion.

The results of the CBA show that the possible returns on investment in storm-resilient housing would be positive and high, which implies that investing in storm-resilient houses can be economically viable. The results also show that the returns are highly dependent on the year when a storm event would take place. If an event would happen early in the housing lifetime, positive returns would be gained from the investment. From a private perspective, positive returns would encourage households to invest in housing resilience. Autonomous adaptation has been occurring and has generally been driven by individual households that are likely to result in substantial investments to increase the resilience of houses.

The CBA results also show that storm-resilient housing would have high benefit-cost ratios. In order to encourage individual investment in storm-resilient housing, the government should consider offering assistance to households that agree to undertake appropriate climate-resilient housing. This may take the form of technical assistance, direct subsidies, or low-interest loans.

1.0 INTRODUCTION

1.1 Background and Rationale

In Vietnam, where local residents consider housing as valuable (yet vulnerable), housing is inextricably linked to climate change. In the central part of the country, cyclones and floods have become more common and have had huge impacts on local housing; these extreme events have been seen as the root causes of household poverty. Recent years have seen an increase in housing damages caused by these hazards in Central Vietnam (e.g., flood in 1999, storm Xangsane in 2006, storm Ketsana in 2009) despite the significant efforts of local governments and agencies for disaster risk reduction. Numerous texts have acknowledged the relationship between housing vulnerability and household poverty, but not many studies deal with the economic aspects of increasing climate resilience for housing. This research, therefore, examined the performance of climate-resilient housing through an economic lens in order to analyze the costs and benefits brought by resilient construction techniques in comparison with nonresilient ones. It also aimed to show that investing in climate-resilient housing can help protect the financial capital of low-income families in the storm-affected areas of Central Vietnam.

Reviewed project reports and the authors' in-field experiences have shown that people living in storm-affected regions in Central Vietnam often belong to low-income groups (poor and near-poor). They spend a considerable amount of their income on housing repairs or reconstruction after annual storms. Sometimes, they fall into debt after disasters as they borrow from friends, relatives, or neighbors much more money than they can afford. Without technical guidance, they unknowingly repeat the same practices, thereby reproducing risks to subsequent storms. Furthermore, most people do not realize that accumulated losses over the years due to natural disasters negatively affect their other development efforts. Thus, this research applied an economic analysis tool, specifically cost-benefit analysis (CBA), to quantify the economic benefits of applying long-term, safety-related measures for housing. This analysis method has proven that investing money on climate-resilient housing is essential in providing at-risk families with positive net benefits by preventing losses.

In terms of policy, most of the current legal frameworks in Vietnam focus on short-term measures (e.g., preparedness, emergency relief, and recovery) immediately before, during, and after natural disasters. In particular, the four onsite guidelines in response to natural disasters, called *Phương Châm 4 t s Châ*, are strictly obeyed in almost all local areas in this region (CECI 2011). In terms of long-term interventions, there are three key documents related to climate change adaptation (CCA) and disaster risk reduction (DRR). These documents highlight the importance of mitigation and adaptation measures for vulnerable sectors (including housing) in disaster-prone regions throughout the country. The first document— the National Strategy for Natural Disaster Prevention, Response, and Mitigation to 2020—was released in 2007. The document primarily aimed to minimize damage and loss of human life and property. With particular focus on climate change issues, the 2008 and 2012 versions of the National Target Programs to Respond to Climate Change are the two other long-term documents that focus on the issue, and provide direction for the planning and implementation of DRR and CCA at the lower local levels in provinces and cities. However, due to their top-down approach, the National Target Programs view CCA and DRR in macro terms without detailed guidelines and instructions for each sector and area at risk. These gaps are compounded by the lack of long-term, responsive strategies to develop climate-resilient housing, particularly in Central Vietnam, which is the most disaster-prone region of the country (Phong and Tinh 2010).

At lower levels, the provincial and city planning strategies play an important role in controlling civil construction through the implementation of planning criteria and building regulations and codes. Building permits are often required in central urban areas, but they are only applied in a limited capacity in the peri-urban and rural regions. In addition, with the exception of planning advice, no transparent legal framework and enforcement measures are immediately apparent to ensure that people in hazard-prone areas follow safe construction (Iglesias 2006; Reed and Thinphanga 2012). In a national assembly meeting in 2012, many of these concerns were highlighted. These have emphasized the need for the national government to take on more active roles in DRR and CCA in view of the apparent insufficiency of local responses in coping with more complicated and unanticipated natural events (Truong 2011). From an economic viewpoint, the current measures being implemented remains limited to supporting local livelihoods and employment development, while investments in applying safe construction techniques to reduce damage costs have thus far been absent.

In this study's literature review, not much research has been undertaken on the economic dimensions of climate-resilient housing. Pompe and Rinehart (2008) addressed the link between hurricane-resistant construction and the role of an insurance system that could reduce people's vulnerability to disaster and the damages they sustain. Sutter, de Silva, and Kruse (2009) also discussed the reduction of insured losses by applying disaster-mitigating measures in fragile buildings. Their studies aimed to ensure the positive net present value of safe construction in areas that are highly at risk to natural disasters. However, there is an absence of clear assumptions for the economic return of utilizing climate resilient strategies. Thomas et al. (2010) conducted a study that analyzed the impacts of natural disasters on household welfare and economy in Vietnam; however, this research limited its conclusion to acknowledging that poorer households are more exposed to climate risks, and that natural disasters generate negative effects on household economy. Again, the analysis of costs and benefits for the development of climate-resilient housing was still missing.

Related to CBA, Pearce, Atkinson, and Mourato (2006) published a book of CBA that focuses on calculating the losses and gains from an event or intervention. This approach is helpful in providing a tool for estimating and comparing the costs and benefits of a project or policy in order to inform decision making. As such, CBA applies equally well in applying climate resilience solutions for housing, especially for the low-income, vulnerable families. This research, therefore, applied CBA in order to analyze and compare the costs and benefits of applying safe construction methods in the local context of Central Vietnam. Such analysis would provide an in-depth understanding of the economic effectiveness of climate-resilient housing.

In Vietnam, after the Reform Policy (called *Chinh sach đôi mơi*) in 1986 was implemented to open the country to the outside world, households began to use new materials (e.g., cement blocks, steel bars, fired bricks, or corrugated sheeting) in housing construction instead of using traditional ones (timber, bamboo) (Chantry and Norton 2008). However, these buildings had no safety-related measures incorporated in the construction (Tinh et al. 2010), thereby generating a so-called *two-fold source of vulnerability* (Chantry and Norton 2008). Over 70% of the houses built during this post-1986 period did not incorporate storm-resistant features; flat roofs, limited attachments between building elements, and a lack of structural bracings were common (Chantry and Norton 2008). In addition, houses in low-lying areas lacked flood-protection features; the absence of upper floors did not allow for safe-keeping of valuable items, whereas the use of hard and heavy materials for roofing traps people inside the house because as they are difficult to open.

Based on the authors' personal experiences in Central Vietnam, housing repairs after climate-related disasters may cost between USD 500 and USD 1,000 at any one time; this may pose a real challenge to low-income families. Many families reported that their homes had already been repaired two to three times, and they expected to do so again in succeeding disasters. This constant need for house repairs constitutes a major setback to the household's ability to improve their living conditions, healthcare, education, and productivity. This practical problem has therefore raised a concern about the effectiveness of current investments on housing construction, and supports the rationale behind the conduct of this study.

1.2 Research Aim and Objectives

The overall aim of this research is to prove the importance and cost effectiveness of climate-resilient housing in Central Vietnam through economic analyses and calculations. To achieve this goal, the following specific objectives were met:

1. To assess the successes and shortcomings of current housing implementation efforts toward climate-risk management and economic efficiency;
2. To clarify climate-resilient housing options appropriate to the local context of the province of Thua Thien Hue (TTH).
3. To analyze the costs and benefits of climate-resilient housing in light of positive net values;
4. To reveal the economic advantages of applying safety-related measures in housing construction in areas of Central Vietnam that are vulnerable to extreme climate events;
5. To draw lessons/policy recommendations to promote resilient housing and the establishment of long-term, enabling institutional environments in the housing sector in Central Vietnam.

2.0 METHODOLOGY

2.1 Hypothesis and Research Questions

This study hypothesized that (1) applying climate-resilient measures for housing can significantly reduce economic losses in subsequent disasters, and (2) climate-resilient construction has a positive net present value in the areas in Central Vietnam that are prone to climate extremes. Accordingly, this research asked the following questions:

1. Why do people waste money on improper housing repairs after annual storms?
2. What would be the appropriate forms of storm-resilient housing in TTH?
3. What would be the economic returns if households incorporated a full package of storm-resistant measures during housing construction compared with houses without storm-resistant measures?
4. What would be the quantitative estimates of returns from including storm-resistant features in new shelters?
5. What policy implications/recommendations can be drawn from this research?

2.2 Research Methods

This research used CBA as its main method. CBA is an established tool for determining the economic efficiency of development interventions. It compares the costs of conducting such projects with their benefits, and calculates the net benefits or efficiency (measured by the net present value [NPV], the internal rate of return [IRR], or the benefit-cost ratio [BCR]). Although the benefits created by development interventions are the additional benefits due to, for example, improvements in physical and social infrastructure, the benefits realized in disaster risk reduction and management (DRRM) are mostly from the avoidance or reduction of potential damages and losses, in addition to the benefits of the primary development interventions.

2.2.1 Identifying storm-resilient housing for the CBA

To apply CBA in storm-resilient housing, it is necessary to define what forms of resilient housing can be used for CBA, and how these forms can be clarified. To do this, this study employed a sequential process of identification that involved four stages: (1) planning housing options, (2) community consultation, (3) finalization of housing options, and (4) CBA calculation (Figure 1).

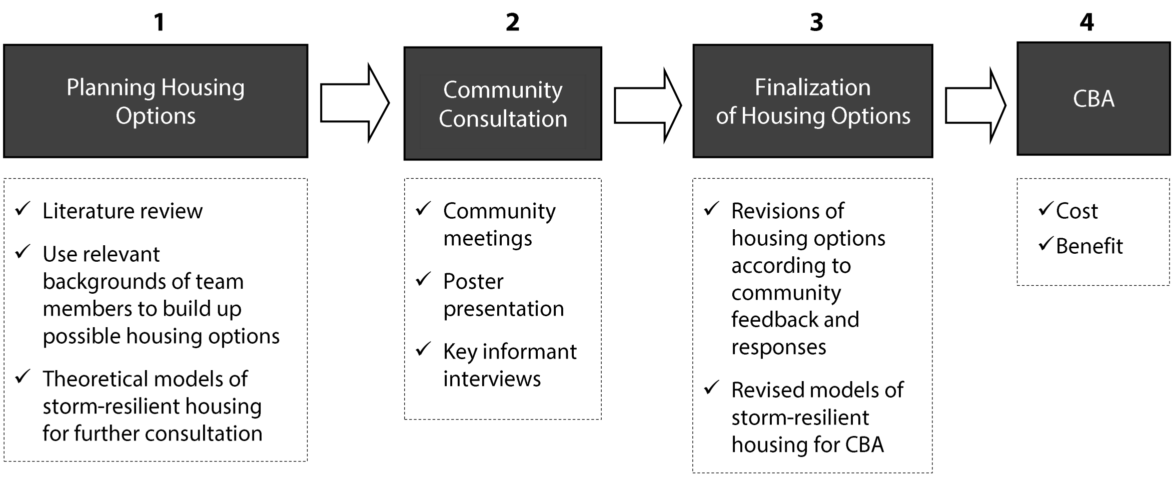

Figure 1. Process to identify resilient housing options for CBA

Based on an intensive literature review and based on the relevant background of the researchers (an architect, an engineer, and an economist), the research team identified two options of storm-resilient housing that may be appropriate to the Hue region. These were the tube houses (*nhàuse*), representing urban areas, and the three-compartment houses (*nhàbagian*), symbolizing rural areas of TTH. As this research is limited to semi-permanent masonry housing, masonry tube and three-compartment houses were considered for further analysis. The researchers then consulted with the local communities, administrative bodies, experts, and practitioners to be able to assess the appropriateness of these two options within the local context, and to determine whether using these two housing types represented the vast population of TTH. The results of the consultation enabled the researchers to revise the resilient housing options prior to undertaking the actual CBA.

2.2.2 Calculating the costs and benefits of resilient housing

Assessment of benefits. In conventional CBA of investment projects, benefits are the additional outcomes generated by the intervention project (e.g., resilient-housing measures) compared to the scenario in which the project is absent. In the case of DRR, benefits refer to the risks that are reduced or avoided (Mechler 2005). The benefits of resilient-housing measures are defined as the avoided damage and loss or the accrued benefits after resilient housing is adopted. Avoided damage (benefits) is the difference in damages and losses under two scenarios: with and without undertaking the resilient housing.

Assessment of costs. The associated costs of a resilient house include the major investment cost for building a resilient house (construction cost), and the operation and maintenance expenses for the house incurred over time (O&M cost). The study focused on the extra costs incurred by a standard nonstorm-resistant house compared with a storm-resistant house.

Economic efficiency. Economic efficiency was assessed by comparing the benefits and costs. Three economic instruments were used in this study to measure the overall economic returns to resilient housing, namely, NPV, BCR, and IRR.[1]

2.3 Analysis Frameworks

In this study, a combined backward- and forward-looking approach in the CBA was applied to assess the current and future storm risks. A review of past storm impacts provided estimates for current risk, while projected changes in climate and exposure were used to estimate risk for the next 30 years (i.e., the estimated lifetime of the house).

In the backward-looking approach, storm damage and loss due to the 2006 Xangsane and 2009 Ketsana storms were estimated using household surveys. The household surveys yielded direct loss (direct damage) and indirect loss (indirect damage) information for housing. Since CBA must be performed for current conditions, the losses (damages) from the past storms in 2006 and 2009 were adopted to present conditions using yearly inflation rates as an adjustment factor in order to convert these amounts into 2013 Vietnamese Dong (VND). By utilizing this backward-looking approach, the authors were able to identify the damages that an average household had experienced in both the 2006 and 2009 storms. The information gathered was then used to build the forward-looking analysis.

In the forward-looking approach, on the hand, the present value of the benefits from resilient housing are likely to be highly sensitive to the expected timing of damage-inducing storm events; yet the occurrence of these storm events are stochastic, or random, with respect to climate change. The researchers had planned to apply the CBA analysis framework proposed by Mechler (2005) to estimate the loss-frequency function (and annual expected damage) by using storm frequency. However, the results of the storm modeling have been, so far, mixed at best. Thus, it was not possible to add probabilities to different intensities of storms. Moreover, the damage caused would be related to the wind speed and direction, and it is difficult to correlate wind speed, damages, and return periods for storms[2] (Nordhaus 2006; Khan et al. 2012).

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[1] For further explanation on these terms, see Appendix 1.

[2] For example, Nordhaus (2006) finds that damages appear to rise with the eighth power of maximum wind speed.

Therefore, the study utilized a scenario-building approach to investigate the future potential economic impacts of storms in Central Vietnam. Specifically, the research investigated two scenarios: (1) Scenario 1: historical frequency and intensity of major events and (2) Scenario 2: increased intensity of major events.

In the first scenario (i.e., historical frequency and intensity of major events), it was assumed that the frequency and intensity of storms in the next 30 years would be similar to that of the storms over the past 30 years.[3] In other words, the same storm intensities as those of 2006 Xangsane and 2009 Ketsana storms would each be repeated once over the next 30 years.

The second scenario (i.e., increased intensity of major events), meanwhile, was based on the assumption that in the future, fewer but more intense storms would likely occur in the region, as suggested by IMHEN (2013). Greater storm intensity may lead to greater damage. In this regard, it was assumed in this study that two storms of similar intensity to the 2006 Xangsane storm would happen in the next 30 years. Accordingly, the avoided damages and estimated BCRs were recalculated, and the results were compared with the first scenario.

Each climate scenario was then run with storm events occurring at different time periods over the expected lifetime of the house. This would ensure a complete view of what the overall economic returns would be in a range of occurrences.

2.4 Key Assumptions

A review of the risk analysis has identified a number of key assumptions driving the CBA design and results, as summarized in Table 1.[4]

Table 1. Key assumptions driving the cost-benefit analysis

Assumption	Value (in VND '000)	Notes (Sources)
Construction costs per house	22,917.06 for a rural house 32,049.81 for urban house	Additional cost of resilient housing Cost of resilient housing minus cost of nonresilient housing per house
Lifetime of house	30 years	Based on FGDs, KIIs, and DWF project
Discount rate	4%	Real interest rate in 2013
O&M costs	2% per 5 years	An increase in additional cost for housing resilience Occurs every 5 years
Salvage value of the house	Using straight line depreciation method	The salvage value of the house at the end of 30 years (the project economic life) was included. The straight-line depreciation method was used to calculate the value of the benefit of foregone damages under the various cases considered. For example, in cases where the storm events occur in the early years of the lifetime of the house, it is still new and the value of the benefit is large. On the other hand, if the events arrive late, the value of the benefit of forgone damages becomes lower, due to discounting.[5]

Note: DWF = Development Workshop France, a French NGO specializing in storm-resistant housing construction; O&M = operation and maintenance

[3] This is a conservative assumption since many storms have passed through TTH in the last 30 years, although these two recent storms have brought significant damages to communities in TTH.

[4] For further details, see Appendix 1.

[5] See Appendix 3 for the sample calculations

2.5 Sensitivity Analysis

The researchers performed a sensitivity analysis using a range of discount rates. Different rates were used because discount rates vary among institutions and by year. A discount rate of 10% is the common base for a CBA study, as widely cited in existing literature (Thang et al. 2013; Do and Bennett 2005; Truong 2011; Tuan and Navrud 2008). As this is an observed nominal interest rate, this approach is valid only if the discount rate is also expressed in real terms; this was not the case in this study. Since the discount rate chosen was based on an observed nominal market interest rate (n), one should expect that this credit market anticipates some future level of inflation (i^*). To arrive at the appropriate real interest rate (r) to use for discounting purposes, the authors chose estimates of expected inflation (i^*), and then used the expected relationship that $r \approx n - i^*$. For example, with the market lending interest in 2013 of 10% and inflation rate of 6%, the real interest rate in 2013 would have been 4%.[6]

In this study, a range of discount rates from 2%–10% was used for the sensitivity analysis. The discount rate of 2% was used because housing is a social welfare development program, with its effect mainly seen in the long-term. The discount rate of 10% was used to describe the current context of the economic crisis.

2.6 Assessing Past Impacts/Damages

Table 2 presents important information on the eight big storms that passed through TTH, which had caused critical housing damages in the last 12 years. Literature indicates that on the average, one big storm directly affects TTH every other year. Household questionnaires were developed to estimate the damage losses on housing due to past storms (e.g., the storm in 2006 and 2009).

Table 2. Eight big storms that affected TTH province from 2000–2012

No	Year	International Name	Velocity and Level of Wind in Hue	No. of Collapsed Houses
1	2000	Storm No. 2	17 m/s; level 7	*No record*
2	2005	Kentak	18 m/s; level 8	*No record*
3	2006	Chanchu	15 m/s; level 7	*No record*
4	2006	Xangsane	24 m/s; level 11	1,185
5	2007	Lekima	22 m/s; level 9	94
6	2009	Ketsana	22 m/s; level 10	376
7	2010	Mindulle		*No record*
8	2011	Haitang		*No record*

Source: CCFSC online database

2.7 Data Collection

The study began with a desktop review of the literature regarding the current housing situation in Central Vietnam, where unmitigated housing damages from climate-related events are associated with limited strategies for developing climate-resilient housing. A further review of recent theories and practices of the CBA methodology was conducted to define the appropriate research strategy to fulfill the objectives of this study.

Focus group discussions (FGD) and key informant interviews (KII) were conducted in order to understand how the impacts of climate change have manifested on the housing in various areas of the study sites. These served as a platform to capture the social acceptability of different housing options, as well as the cost of building resilient housing.

[6] See Appendix 1 for the formulae for estimating a series of real rates that are specific to each year or time period.

Finally, a field survey was conducted to collect primary data within real-life context in order to support the data analysis. The data collected were related to the underlying contextual and intervening conditions of increased housing vulnerability and the economic gain and loss of at-risk low-income households after annual cyclones. Field data were collected through household questionnaires, FGDs, and observations. Photographs were also taken in some surveyed houses and sites to examine the accuracy of information gathered from interviews, where necessary.

The field survey lasted for six days (three days per site), from 15 to 20 January 2014. It was conducted by a group of five people, including two research team members and three graduate students who have had experiences in undertaking household surveys. In the course of this research, policy and decision makers and housing experts were consulted with regard to issues on policy reforms related to climate-resilient housing—particularly, how to adjust and modify policies and legal frameworks to support a resilient-housing system in storm and flood zones. A total of10 FDGs and 15 KIIs were conducted. Through these FGDs and KIIs, policy makers and experts were consulted about policy alternatives and shifts in construction practices.

2.8 Data Analysis

The research team collected both qualitative and quantitative data using standard methodology. Qualitative data were analyzed through textual analysis, and quantitative data were analyzed by using SPSS and Microsoft Excel software. Secondary data were obtained from published academic and consulting agencies, as well as internal documents from government and nongovernmental organizations. Primary data were collected through FGDs, KIIs, and household surveys. About 10 FGDs with community leaders and local people, as well as 200 household surveys, were conducted. Questionnaires were administered by the research team. About 15 semi-structured interviews with key informants (e.g., public officers, village heads, knowledgeable persons, and chiefs of mass organizations) were carried out to validate and complement the information gathered.

This research was intended to extend the analysis beyond CBA in order to examine relevant policy and legal frameworks involved for the development of climate-resilient housing, such as home loan interest rate supports, housing insurance programs, design standards for resilient housing, and construction monitoring criteria for hazard prone areas, etc. Based on the calculation of the two implementation options (i.e., three-compartment house and tube house) using private and social discount rates, the research generated policy implications for each option, where their appropriateness was assessed in consultation with experts and agencies involved through FGDs. KIIs with key persons in the field were also used to further assess their validity and applicability before reaching a conclusion. This allowed a comparison of cost and effectiveness among the policy-related recommendations.

3.0 DESCRIPTION OF THE STUDY SITE

3.1 Loc Vinh Commune and Huong So Ward in Thua Thien Hue

The study area is located in one of the most vulnerable provinces in Vietnam, Thua Thien Hue (TTH). This province is close to the sea where tropical cyclones originate and strike every year (Figure 2). Given the huge impact of storms on local housing compared with other climatic events (e.g., floods and droughts), cyclones are one of the biggest hazards to the local communities of TTH (Tran and Bui 2010). In recent years, housing damages due to storm-related disasters (e.g., storm Xangsane in 2006 and Ketsana in 2009) have increased despite the DRRM efforts of local governments and aid agencies.

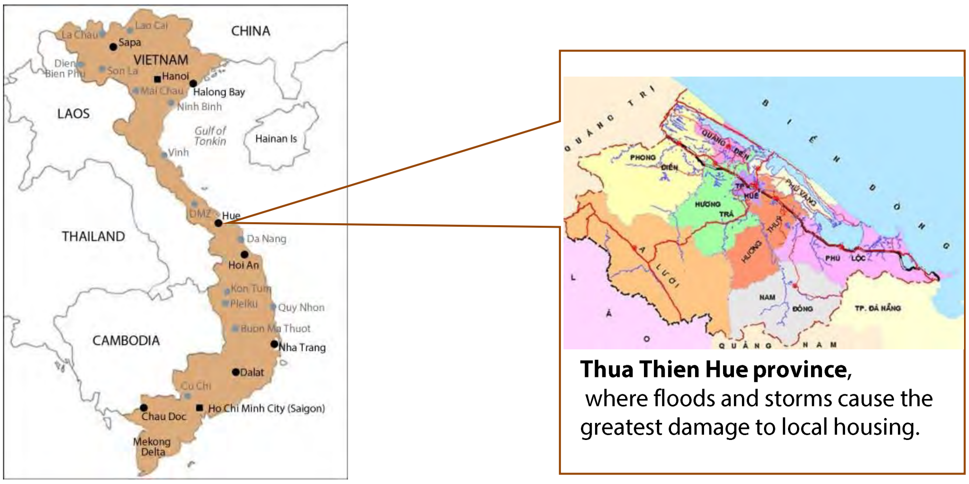


Figure 2. The study site, Thua Thien Hue province, Central Vietnam

Source: TTH Provincial Government (2013)

Geographically, TTH has an area of about 5,033 square kilometers. Agriculture is the largest employer (57% of the total labor force), and will continue to play a significant role in employment creation and poverty reduction in the province. The occurrence of storms is hard to anticipate accurately in Central Vietnam, particularly in TTH. According to the observations of the TTH Provincial Committee for Flood and Storm Control (PCFSC 2008), recent storms seem to have decreased in number but have increased in strength. However, the observations also showed that natural disasters in this province tended to last longer and were becoming more unpredictable. Every year, TTH suffers from five to eight storms, followed by long-lasting rains and heavy floods. One of the largest and most memorable events was the storm Xangsane in 2006.

According to the national housing census in 2009, the urban population in Hue increased from 27.6% in 1999 to 36.1% in 2009, with an average rate of growth of 0.85% per year (GSO 2009). Although no official estimates of present and future urban population in Hue are available, the proportions of urban population at certain years in the future can be estimated based on the annual rate of 0.85%. Based on data, the proportion of urban population in the total province population would reach 39.50% in 2013, 43.75% in 2018, and 48.00% in 2023 (Figure 3). In addition, the rural folk continue to migrate to the city in search of a job or better life. This poses a real challenge in meeting increased housing demands in Hue City in the next 5–10 years. Under this pressure, hazard-prone areas in peri-urban, riverside, or seaside locations are increasingly being occupied by the urban poor and low-income households, whose houses are often located in unsafe areas. In addition, planning and zoning criteria and building codes for DRR are difficult to apply in housing construction/renovation as their sites are frequently outside the urban areas addressed in city planning.[7] Consequently, this makes them more vulnerable to future climate events.

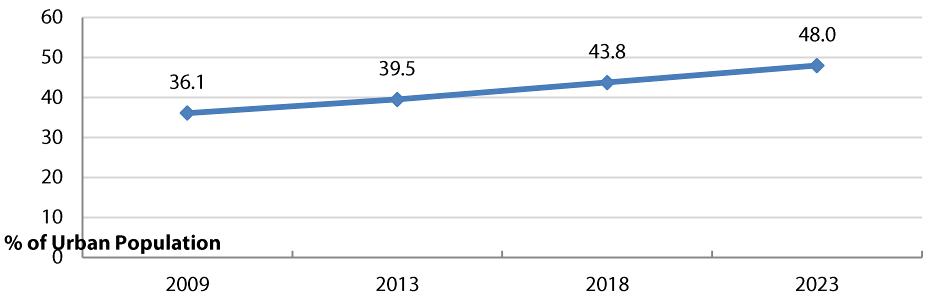


Figure 3. Urban population growth in Thua Thien Hue

Source: GSO (2011)

[7] In Vietnam, houses built in the urban area of the city planning must have a building permit before construction.

People affected by climate disasters—predominantly cyclones—in TTH often belong to the poor and low-income groups (Phong and Tinh 2010; Tran and Bui 2010; Tran et al. 2013). After disasters, they become poorer because they use a considerable amount of their income for house repairs or reconstruction. Without technical assistance for safe construction, they follow the same practice as before, inadvertently reproducing risks without being aware of it (Chantry and Norton 2008). In addition, a limited number of people accumulate losses due to ongoing housing damage over the years, which badly affect other development efforts their family might have otherwise pursued.

Two extremely climate-exposed areas in TTH, one in a rural and one in an urban area, were selected as the specific study areas of this research. These were Loc Vinh commune (for rural setting) and Huong So ward (for urban setting) (Figure 4). Loc Vinh commune in Phu Loc district is located near the Chan May Bay, where storm risks are high and pose the biggest hazards to people living there. Housing in this commune mainly follows the three-compartment form for the main house, with various types of spatial expansion (sub-house) attached to the main house. On the other hand, Huong So ward in Hue City is located in a peri-urban area where a mix of rural and urban housing can be found. In this ward, tube houses are commonly found and are increasingly favored by the local residents. According to the FGD participants, the exposure to storm hazards in this ward, due to its location far from the sea, is lower than that in the sea-contacting location of the Loc Vinh commune. This is reflected in the local construction practices here, where safety-related issues seem to be addressed in a limited way.

Historically, similar to other provinces of Vietnam, the National Reform Policy in 1986 has transformed housing in TTH, resulting in an intense import of new products and commodities, most common of which were new construction materials (i.e., cement, steel, or corrugated sheeting) and methods. However, limited understanding of their proper use in local construction has resulted in an increase of housing vulnerability to disasters (Chantry and Norton 2008). The recent surveys done in this study in the region of Central Vietnam revealed that post-cyclone expense for house repairs/reconstructions take up a considerable amount of the families' household budget. Many of them said that their houses had already been repaired several times, and they expected this reality to continue with future storms.
This makes it more difficult for these households to get out of poverty, and improve their living conditions, healthcare, education, and productivity.

Figure 4. Site map of Loc Vinh commune and Huong So ward, Thua Thien Hue province

4.0 SELECTED HOUSING TYPES

The 2009 National Census officially categorized housing in Vietnam to correspond to four types, in accordance with the number of strong parts in the building structure: (1) permanent (*kiên cố*), (2) semi-permanent (*bán kiến cố*), (3) less permanent (*thiếu kiên cố*), and (4) temporary (*đơnsơ*) (Table 3) (GSO 2009). A permanent house comprises all three strong parts (foundation, walls, and roof), whereas semi- and less-permanent types consist of two and one strong part/s, respectively. A temporary house has no secure parts in its structure.

According to the 2009 census, majority of the local housing in TTH is composed of permanent and semi-permanent houses (54.3% and 40.9%, respectively); less-permanent and simple ones represent a very small percentage (2.3% and 2.5%, respectively). In this time of rapid urbanization and with the increasing availability of new materials and new construction methods, less-permanent and simple houses would likely disappear in the near future to leave room for permanent and semi-permanent ones. In addition, most of the permanent houses will be capable of withstanding storms, due to their location in central urban areas, less exposure to hazards, and their having been constructed using strong reinforced-concrete skeletons.

The 2009 national census reported that the proportion of semi-permanent houses in Vietnam decreased by 1.2% from 1999 to 2009. Applying this rate to TTH, the proportion of semi-permanent houses in this province is estimated to go down to 36.1% in 2013, 30.1% in 2018, and 24.1% in 2023 (Figure 5); but these proportions are still large. In an era of increased occurrences of climate-related events (particularly storms), building resilience capacity for this housing type (semi-permanent) is crucial in addressing future disaster risks. In addition, the field surveys (i.e., the post-Ketsana housing reconstruction in 2010, the HFH survey in 2010, or the IIED research in early 2013) undertaken by the researchers have shown an escalation in the number of non-resilient semi-permanent houses in the peri-urban and rural areas of TTH, where climate exposure is higher and resources and capacity for coping with disasters are limited.

The national census of 2009 restricted the assessment of structural stability simply in terms of the type of materials used. In this assessment, reinforced concrete, brick, and stone (masonry structures) were defined as lending structural safety to the building; whereas wood, bamboo, thatch, or earth were considered unsafe (GSO 2009). From the perspective of disaster resilience, this means that the public automatically perceived these "stronger" structures as "safer," and therefore preferred. However, observations after storm Xangsane (2006) and Ketsana (2009) revealed that most physical housing damage occurred where masonry materials were used.

Table 3. Percentages of housing types in TTH

Indicator	Permanent	Semi-permanent	Less-Permanent	Simple
Percentage (%)	54.3	40.9	2.3	2.5
Number of houses	145,753	109,785	6,173	6,710

Source: GSO (2009)

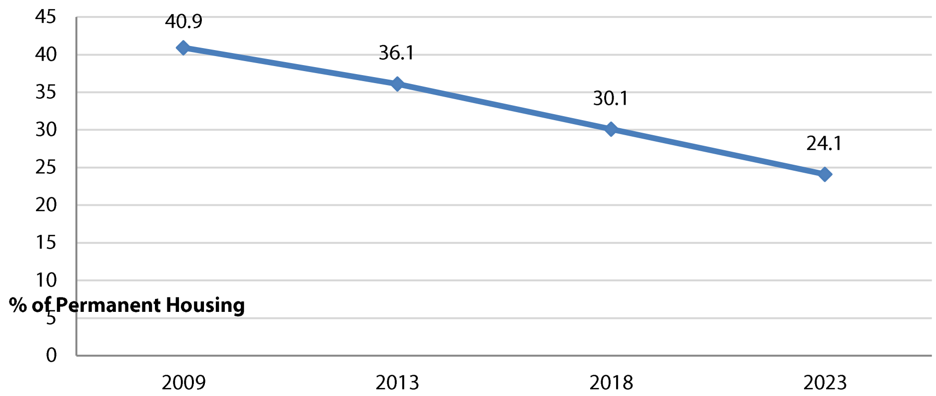


Figure 5. Estimated trend of semi-permanent housing in TTH
Source: GSO (2009)

In this study, two options for storm-resilient housing were identified to be appropriate to TTH. These are the tube house for urban areas and the three-compartment house for rural areas (Figure 6). As this research is limited to semi-permanent masonry housing, the masonry tube and three-compartment houses in TTH were examined in light of storm resilience for the CBA.

Various forms of three-compartment and tube housing were discussed extensively during the pilot survey, and were assessed to be good representatives of rural and peri-urban areas in TTH. Based on these preliminary results, this research drew out the standard design and cost estimation for these housing types. *Resilient housing*, as used in this study, refers to the capacity of not only individual buildings but also the settlement and community where houses are located in a particular pattern or layout. According to Development Workshop France (DWF), after over 10 years of working in the field of post-disaster housing reconstruction and disaster management in Central Vietnam, three-compartment and tube houses were highlighted as the two most common types of local housing in this region (DWF 2011). Three-compartment houses are commonly seen in rural areas of TTH province, while tube houses are widely found in the peri-urban locations (Figure 7). These types of housing were selected for the CBA of this research.

Tube House (Nhàống)	**Three-Compartment House (Nhàbagian)**
	
	
	

Figure 6. Some surveyed tube houses and three-compartment houses on site

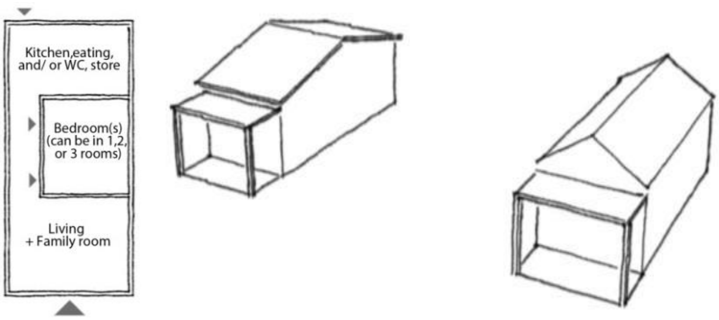


Figure 7. Typical floor-plan (left) and 3D illustrations of tube houses in TTH

4.1 Tube Housing

The tube house has a rectangular floor-plan that incorporates a separate room or rooms within a larger perimeter of frequently twice the size. This housing type saw fast growth in the urban areas of Vietnam during the urbanization period, and is thus an outstanding representative of the urbanization age in Vietnam. Over the last decade, the residential lands of new urban areas have usually been divided into long and narrow plots, within which the rectangular form of tube house is geometrically consistent (Figure 8).

Consistent with the similar form and spatial layout, the construction methods and materials used in tube houses are also alike. Clay tiles or corrugated iron sheets are used for roofing, while brick or cement blocks are used for walls, and stone, cement blocks, or brick for foundation (Table 4). Some of the local people have added tie beams on the foundation or at various levels of their houses in order to strengthen the structure. According to the current market prices provided by local construction companies, the average cost for house construction is about VND 2.6–3.2 million per square meter of floor area within normal conditions. This price may go up or down depending on specific conditions at each location.

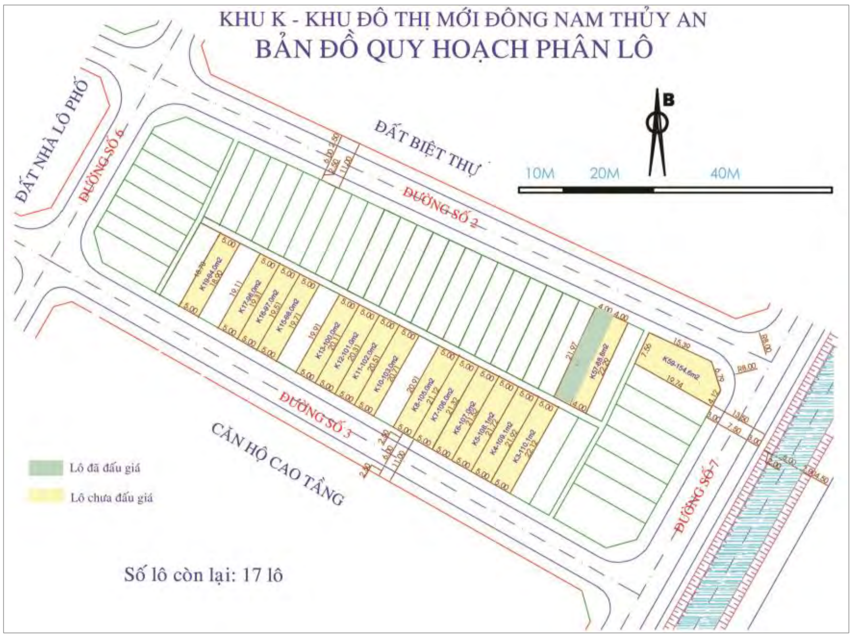


Figure 8. A new urban residential area of TTH with the domination of long and narrow plots that show geometrical suitability with the tube house form

Table 4. Common materials used for parts of tube houses

Foundation	Walls	Roof
Stone	Cement blocks	Corrugated iron sheets
Cement blocks	Bricks	Clay tiles

4.2 Three-Compartment Housing

The three-compartment house is strongly reflects the TTH traditional housing, known as *Rường* houses, where the division of the internal space into three compartments is the most outstanding feature (Figure 9). This layout is culturally appropriate to local lifestyles where the middle space is used for altar or worship, the side spaces for sleeping, and the front mixed space for living and general family activities.

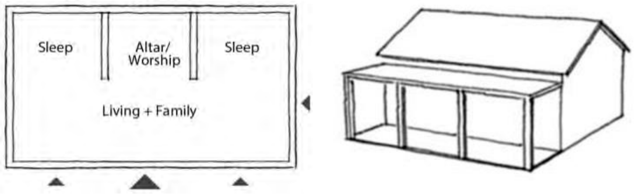


Figure 9. Typical floor-plan (left) and 3D illustration of three-compartment houses (right)

There are quite a few studies that have looked at the disaster resilience capacity of this housing type, whereas some have just mentioned it in general. For instance, DWF identified the three-compartment housing as the typical type of rural housing in TTH province (Tran and Bui 2010). Kobayashi, Duc, and Tanaka (2012) assessed the housing conditions in a hazard-prone rural village of TTH and assessed the three-compartment house to be the most common type of local housing; it covered a predominant number of surveyed houses, ranging from traditional to modern types. This study also showed that rural households used the three-compartment structure in the main house to accommodate important living functions of the family, while the attached spatial extensions were used for subfunctions (Kobayashi, Duc, and Tanaka 2012). In a study undertaken by the current research team in a rural area of TTH in early 2013, the three-compartment type of housing was again the most preferred by the local people (Figure 10). These studies showed that three-compartment housing is the most common type of local housing in rural areas of TTH. In terms of construction, the more contemporary three-compartment houses are not made of timber as they had been before. Instead, masonry materials such as cement, steel, or brick are now commonly used, although frequently without strong bracings, details, and connections for storm resistance (Tran et al. 2013; Chantry and Norton 2008).

According to Nguyen (2002) and Tran et al. (2012), the vulnerability to cyclones of the houses in Vietnam is commonly exposed through two ways: site planning (settlement patterns) and building design. Problems in site planning are often exhibited when houses are built in locations exposed to climate hazards and storm winds. From past experience, people usually know which locations or places are prone to hazards and disasters. However, due to economic constraints, they usually have no choice regarding plot selection. In terms of settlement patterns, people are often unaware of some conditions that may intensify storm impacts, such as arrangement of buildings that create wind-suction bags (Nguyen 2002) or equal arrangement in settlement planning that create no obstructions to wind-flow (Tran et al. 2012).

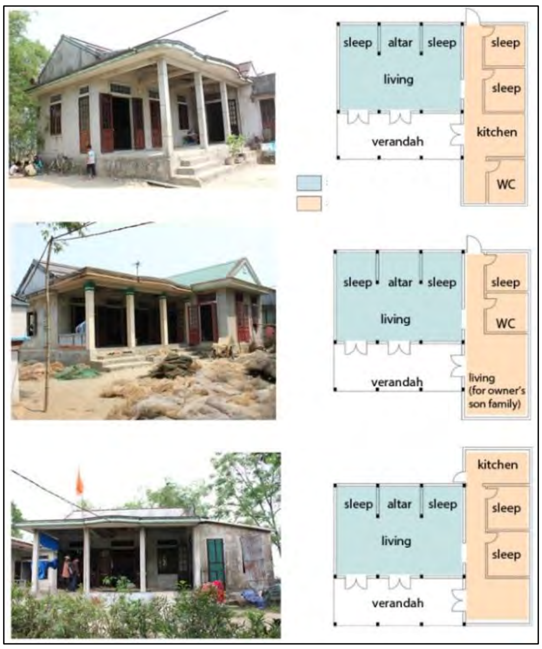


Figure 10. Three-compartment houses in rural areas of TTH

Source: Tran et al. (2013)

5.0 RESULTS AND DISCUSSIONS

5.1 Technical Issues Related to Storm-Resilient Housing

The technical problems of local housing construction in terms of storm resilience at the two research sites (i.e., Loc Vinh and Huong So) were identified in this research. Some of the mistakes, such as the lack of wall bracings or roof connections, are repeatedly made by local builders. In addition, the researchers investigated the cyclone-resistant shelters provided by agencies (i.e., the DWF in Loc Vinh), and assessed the local construction techniques applied to the houses. This allowed the researchers to identify the key technical principles for storm-resilient construction. In support of this, key informant and household interviews were done to enable the researchers to provide estimated costs for such methods of storm-resilient construction.

To summarize, this section is divided into three parts. The first part discusses the common technical failures of local construction in terms of storm risk reduction. The second part clarifies key fundamental principles that local construction needs to conform to in order to ensure safety and resilience to storm hazards. The last part concludes with key construction techniques for building storm-resilient housing, with particular focus on two selected housing types— three-compartment and tube housing—in line with a delivery of cost estimations for each type. These estimates were subsequently used in the CBA of the resilient-housing options.

5.1.1 Technical failures found in local construction in terms of storm resilience

From onsite observations and discussions with local builders, some limitations were found in the local construction that would likely increase the risk exposure of houses to storms. Commonly, the roof's pitch has an angle of below 20°; three instead of four iron rods (usually 10 mm in diameter) are used inside reinforced concrete pillars; or the roof is attached instead of detached to cover semi-open spaces such as a veranda or lobby (Figure 11). In addition, based on in-field experiences accumulated through the recent research and practice projects, several key technical failures have been identified in the local construction practices in Loc Vinh and Huong So. The enveloping walls are quite thin, usually 10 cm in thickness, and are unable to withstand strong winds. Continuous beams on the top of walls and bracings between building elements (pillars and beams, walls and roof) and between roof parts (trusses, purlins) are lacking. Likewise, there is a lack of strong hatches to close the doors and windows securely during storms, or there are no strong and enclosed rooms inside the house that can serve as a shelter for occupants in case of catastrophic storms.

As witnessed from the effects of storm Haiyan in November 2013, in which the storm's strength was beyond conventional wind-measurement scales, peoples' perceptions of storm resilience for shelter and settlements need to be adjusted. In particular, it is economically impractical for at-risk groups, mainly the poor and low-income people, to build an extremely strong house to cope with such strong storms when the probability of occurrence is very low. Instead, they have to understand the potential impacts of such calamitous events and to prepare the necessary, cost-effective solutions that would reduce human losses and protect valuable items (furniture or production tools). As seen in Tacloban, Philippines, when storm Haiyan hit the country, its strength exceeded the local preparedness capacity and triggered unexpected huge damages and losses—thousands of casualties and innumerable destroyed shelters. After the cyclone passed through Tacloban, Central Vietnam was forecasted as Haiyan's second destination. Fortunately, it moved offshore along the country, and landed on North Vietnam with a much lower strength. This means that the probability that a calamitous storms such as Haiyan in the region of Central Vietnam would occur is positive; stakeholders should then consider that such an event can occur in the future such that vulnerable communities can plan for appropriate coping strategies.

Building Element	Failures in Local Construction
Roof: Small pitch (≤ 20º)	
Load-bearing pillars and beams: Three iron rods inside	
Walls: Thin walls (thickness ≤ 11cm)	
Foundation: No consolidation elements	
Doors and windows: No strong latches to stabilize them in storms	

Figure 11. Technical failures of local construction practices in terms of storm resilience

Damage is often unavoidable in such catastrophic storms; but it is essential to identify the acceptable risk levels in order to identify which protection efforts should be prioritized. In all cases, human life is the first priority for protection, followed by property and livelihoods. The design of climate-resilient housing is required to prepare solutions for human-loss prevention. The concept of "safe failure" proposed by the Institute for Social and Environmental Transition (ISET) in 2012 is very likely to meet this demand. In this system, a "strong box" that functions as a "safe failure" could be used as a shelter by the family during a catastrophic storm (Figure 12). This "strong box" can be a bedroom, a store, or a toilet/bathroom made of a secure, enclosed structure (e.g., reinforced concrete) based on the economic capacity and functional need of each household. This measure is quite cost effective, as only a small expense will be added to consolidating one room in a normal house.

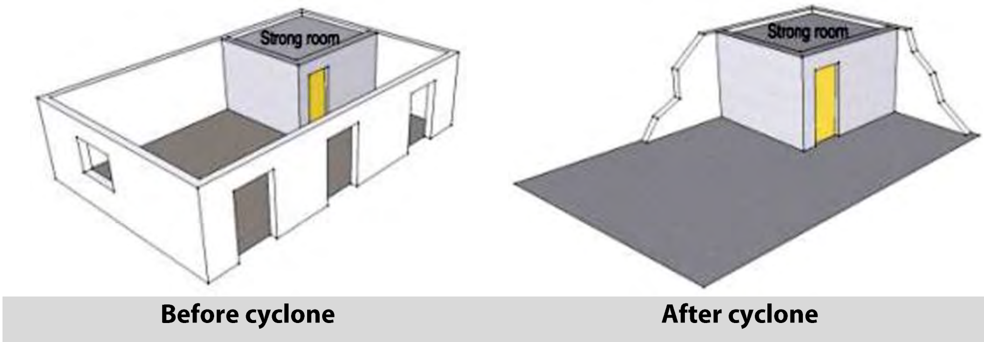


Figure 12. A strengthened room is a safe shelter during big storms

Interestingly, this “safe-failure” feature can be found in the reality of Loc Vinh where annual storms are the biggest hazards to local housing and settlements. At the household level, some surveyed local houses had this feature through the use of an enclosed reinforced-concrete toilet inside the house. However, only a few of them are aware of this safe-failure feature; they use it for storing valuable items on the top floor of this toilet. At the community level, this feature is seen in public buildings when they are used as the safe places for evacuation during disasters. Based on the results of the group discussions, people use these multi-storey schools and office buildings (usually 2–3 stories) made by reinforced concrete as shelters during storms. These public buildings are often located within a short walking distance in at-risk communities to allow the people to access the structure during storms. All interview respondents were highly appreciative of these public buildings as they protect the people from death or injury caused by natural disasters.

5.1.2 Fundamental principles for storm-resilient construction

The assessment of the current housing situations at the two research sites showed that housing vulnerability to storms is commonly exposed through two ways: site planning and building design. The problems in site planning are exhibited through the unfavorable settlement patterns to storm winds, while that of building designs are through the shortage of strong bracings and connections between building parts. Based on the experiences from recent storms, people are able to realize which areas are vulnerable. However, due to economic constraints as most of the affected families belong to the poor and near-poor groups, they are unable to choose a safer location; instead, they settle for cheap plots in hazard-prone areas. Likewise, the local authorities and communities have limited understanding of the planning issues and the link between planning solutions and storm risks. For example, the inappropriate arrangement of buildings may create wind-suction bags and intensify wind pressures during storms. The parallel organization of buildings also provides no obstruction to wind flow. In addition, in case of storms followed by storm surges and/or long-lasting heavy rains, site-planning measures have to take into account further means of addressing these risks from hazards following a storm. As witnessed in the storm Ketsana in 2009, the storm surge following the storm was not widely announced to at-risk groups, which resulted in heavy damages to local housing and property.

Therefore, building on higher locations (e.g., multi-storey buildings) or storm shelters (e.g., schools) inside at-risk communities, in concert with a detailed action plan for timely evacuation and rescue, is essential to reduce risk and improve storm resilience. Other than these disaster-resistant features, the site plan of settlements should address climate responsiveness for human comfort within neighborhoods (e.g., by creating more open public spaces, green and water areas, etc.).

Accordingly, this research analyzed the costs and benefits of constructing storm-resilient shelter; thus, this study has focused more on the issues related to building design (rather than settlement planning). The technical details related to housing design and construction for storm risk reduction are then discussed in order to identify the key technical principles and techniques that would enable the communities in Central Vietnam, particularly TTH province, to develop storm-resilient housing options. Based on the consultations done with built-environment professionals, the communities at the study sites need storm-resilient housing that address safety-related measures for all parts of the building; in which the methods for strengthening the foundation, walls, and roofs are utilized at the same time.

Based on the interviews with DRR experts, on onsite observations, and on group discussions with local builders, eight fundamental technical requirements (1–8) to enhance storm resilience for housing emerged:

1. *All parts of the house's structure should be securely attached by strong bracings and connections.* A continuous reinforced-concrete (RC) skeleton, including pillars and beams, need to be used to make the main structure stable. The roof frame should be strong enough and should be attached to the main structure. The roof covering needs to be strongly tied to the roof frame.
2. *The roof's pitch should be in the range of 30°–45° angle to limit wind-suction pressures* (Figure 13).

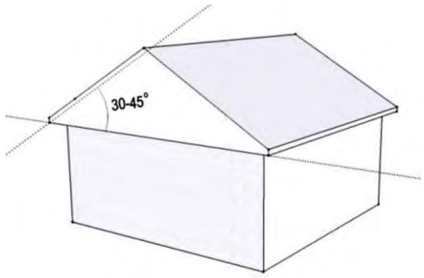


Figure 13. Favorable roof angle of 30°–45° for storm reduction

3. *A simple building should be formed to minimize obstruction to storm winds.* Square and rectangular plans are favorable to limit wind pressures. When more complicated forms are used, consolidation measures must be added to stabilize the building. In houses with a rectangular plan, the ratio between the length and the width needs to be smaller than 2.5.
4. *There should be one strengthened room within the main house that would function as the "safe failure" for shelter in cases of calamitous storms.* This can be done by a reinforced concrete skeleton and slab.
5. *Veranda(s) should be separated from the main house.* The length of roof cantilevers (e.g. canopies or roof edges) should be limited outside the walls.
6. *Limit the openings (windows, doors) but ensure adequate natural light for internal spaces* during daytime; the size of openings on the opposite walls should be similar.
7. *Doors and windows must be tightly closed and capable of resisting strong winds.*
8. *Wind-breaks surrounding the house should be built, in form of trees, hedges, or other vegetation;* ensure there is a safe distance between these wind-breaks and the main house.

The cyclone-resistant houses rebuilt by DWF after storm Xangsane at the research sites had seven out of eight of the above principles (except the fourth principle of using the "safe failure"); this functioned effectively in the succeeding recent storms that passed through the research sites.

5.1.3 Storm-resilient construction techniques and associated cost estimations

The researchers were able to identify the key construction techniques for storm resilience in each part of the building (foundation, walls, roof, and doors and windows) based on the technical principles (Items 1–8) for storm resilience mentioned earlier and based on the discussions with built-environment professionals and local builders on safe construction (Table 5). Accordingly, all parts of a house, from foundation to roof, seemed to have an equal role in protecting the house from storm impacts, although a slightly higher importance was given to the walls and roof (29%) compared to the foundations and doors/windows (21%) (Figure 14). Therefore, the design of storm-resilient housing needs to address safety-related measures for all building elements separately, as well as incorporating methods to connect all of them securely.

Table 5. Involvement of building parts into technical principles

√: Involved

Technical Principle	Foundation	Walls	Roof	Doors and Windows
1	√	√	√	√
2			√	
3	√	√	√	
4	√	√		
5		√	√	
6				√
7				√
8	Not relevant due to employing items outside the house (trees, neighboring buildings, etc.)			

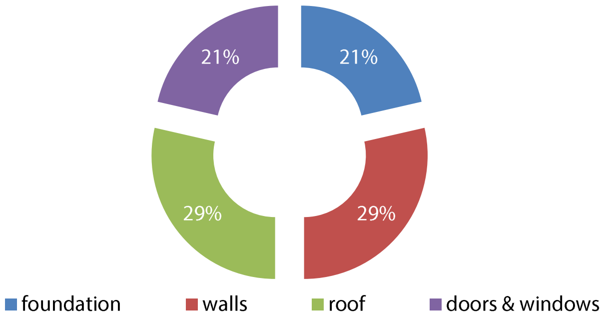


Figure 14. Involvement of building parts into technical principles

The researchers used the above technical principles to further discuss with DRR technical experts and local builders—and accordingly identify—the key technical specifications required in each part of the building to build a storm-resilient housing (Appendix 2). These specifications were subsequently incorporated into the CBA of the construction of storm-resilient housing (Appendix 2).

5.1.4 Cost estimations for storm-resilient construction techniques

Based on the consultations with DRR experts and built-environment professionals and on the group discussions done with local builders, it was found that using the technical features of storm resilience would increase construction cost. The rate of cost increase would depend on the location of the building site, although the variance would not fluctuate largely. The DRR experts indicated that the rate of cost increase for storm resilience would be primarily based on the targeted storm-wind level (e.g., Level 12 of the Beaufort Scale) that designers would aim for. According to the DRR expert-respondents, the higher the wind levels against which the house would be reinforced, the higher the cost of construction would be.

However, it would not be practical to design and build a very strong house to withstand calamitous storms (e.g., Haiyan in 2013) because the probability that such event is very low; building such extreme structures exceeds the economic capacity of the low-income households. The DRR experts interviewed had indicated that recent post-storm housing reconstruction projects in Central Vietnam have frequently targeted Level 12 of the Beaufort wind scale for the wind-resistant capability of rebuilt houses. For stronger storms, evacuation is the best option to prevent loss of human life as the houses may not be able to withstand winds of higher strengths—they could collapse anytime.

Accordingly, this research came up with housing options capable of withstanding windstorms of up to Level 12 in the Beaufort scale. This is in line with the deployment of necessary measures for uncommon but calamitous storms. Applying the "safe failure" concept given by the ISET (2012) by using a strong box/room inside the house (Tran et al. 2013) would address this requirement. Based on the discussions with affected households, local builders involved in local housing construction, and DRR experts, it was estimated that the extra costs associated with the use of storm resilient construction techniques would be higher for the foundation and walls than that for the roof and door/windows. Figure 15 illustrates the estimated additional cost it would entail in building storm-resilient housing, whereas Tables 6 detail how resilient techniques in construction can be achieved.

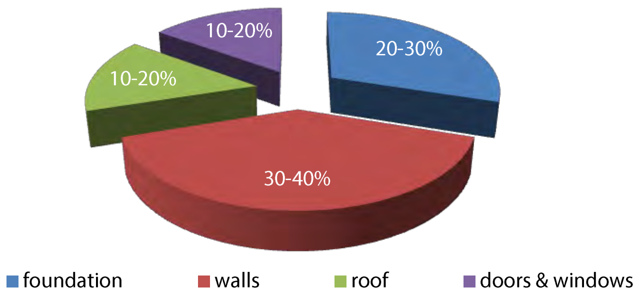


Figure 15. Common percentages of extra costs in building safer shelter against storms

Table 6. Estimated extra cost of construction techniques for storm resilience

Technical Details for Storm-Resilient Housing	Estimated Extra Cost (% Increase of Total Cost per Part)
Foundations	
Width of pillar's foundation (main structure) = 1.2 m Width of pillar's foundation (for substructure: veranda, balcony) = 0.8 m	20%–30%
Depth of pillar's foundation ≥ Width of pillar's foundation	
RC continuous beam to connect the foundation's footings: Beam height = 150 mm; 4 iron rods (inside) Beam width = 220 mm (must be similar to or thicker than upper walls)	
For substructures (veranda, balcony): Beam height = 80 mm, 2 iron rods (inside) Iron rods = 12–14 mm (in diameter) Iron wires for binding = 6–8 mm (in diameter)	
Walls	
RC pillars in walls ≥ Wall thickness 4 iron rods (diameter ≥ 10 mm) Pillars' height ≤ 4 m	30%–40%
Wall thickness = 150–220 mm Bricks must be laid in walls in horizontal direction RC pillars must be placed in walls, 2.5–3.5 m apart Two RC continuous beams at foundation and roof levels	
Connection between walls and RC pillars: By iron rods put in pillars, 0.4–0.5 m in length per rod, 0.5 m apart	
For calamitous storms: Safe failure applied through a closed strong box (room) inside the house	

Table 6 continued

Technical Details for Storm-Resilient Housing	Estimated Extra Cost (% Increase of Total Cost per Part)
Roof	
Roof frames securely attached to the main structure Roof covers securely tied to roof frames RC is commonly used for roof frames in Hue region	10%–20%
Iron rods (diameter = 6 mm) or iron sheets put in roof frames to connect with roof purlins	
Diagonal bracings by iron rods (diameter = 6 mm) on roof frames with adjusters (*tăng - đơ*) for tightening	
Roof covering by corrugated iron sheets: Iron sheet's thickness ≥ 0.4 mm, V-shaped steel bars on iron sheets, 2.5 m apart Roof covering by clay tiles: Concrete bars are used to put on tiles, 2.5 m apart	
Roof cantilevers (outside the walls) ≤ 20 cm, placed in concrete bars, and have a gutter underneath	
Ceiling placed under sloping roofs Roof's pitch = 30°–45°	
Doors and Windows	
Doors: Door-frame size = 100 x 80 mm, Wooden panel for below part (2 cm thick) Two-leaf doors: A wooden bar is used as the latch (through a Z-shaped iron plate) in the middle of doors Windows: Window-frame size = 40 x 80 mm All doors and windows must have bolts on top and bottom	10%–20%
TOTAL Percentage of cost increase for the whole building = mean of cost increase per building part (foundation, walls, roof, and doors and windows)	17%–27%

Note: RC = reinforced concrete

The construction techniques for storm risk reduction and their associated additional construction costs given in the above table were subsequently applied to the two selected housing types included in this research. According to DRR experts and local builders, although tube and three-compartment houses have different building forms, the percentages of cost increase in building these kinds storm-resilient houses are generally similar. This is because the same kinds of materials and construction methods are used.
This research, therefore, took these percentages of cost increase as the backbone in calculating the costs and benefits of storm-resilient houses.

5.1.5 Estimating the total damage per household in the study sites

A total of 102 households in Loc Vinh and 86 houses in Huong So were selected for the final household survey sample. The household survey aimed to collect direct and indirect loss information.[8] Direct monetary losses included the structural and asset damages incurred by the household due to the storm. Meanwhile, indirect monetary losses included those costs that were incurred due to the disaster, although they did not include damaged items. These costs also included business interruption costs for those businesses that did not sustain direct damage, but whose operations had been suspended due to various reasons (e.g., discontinuity of supply, absent workers/employees, power interruptions). The fees paid to treat those people were also accounted in the indirect costs (Table 7). Meanwhile, the average household damage estimates due to storms Xangsane in 2006 and Ketsana in 2009 are reported in Table 8.

Table 7. Quantifiable disaster impacts

Monetary		Non-monetary	
Direct	**Indirect**	**Direct**	**Indirect**
Housing partially and totally damaged Damages to household assets	Business interruption Evacuation costs Health and medical fees	Anxiousness Sickness	Trauma Ties between family members affected

Table 8. Total damage per house (in '000 VND)

Storms	Total Damage	Total Damage in 2013	Total Damage per Standardized House
Three-compartment house (house in rural area)			
Xangsane, 2006	28,295	63,543	84,448
Ketsana, 2009	22,925	35,714	42,428
Tube house (house in urban area)			
Xangsane, 2006	30,356	68,171	90,599
Ketsana, 2009	21,725	33,844	44,979

The total damage per household was computed to be VND 28,295 million and VND 22,925 million for Xangsane in 2006 and Ketsana in 2009, respectively. However, in order to take into account the inflation of past years, these figures were converted using yearly inflation rates (CIA World Fact Book 2013). The total damages in 2013 figures are reported in column 3 of Table 8.

5.2 Cost-Benefit Analysis of Storm-Resilient Housing

5.2.1 Three-compartment housing

Scenario 1: Historical frequency and intensity of major events. The NPV, IRR, and BCR in this scenario were calculated using storm events occurring at different time periods over the lifetime of the house. The first option (i.e., the best case) was chosen with the assumption that a storm with the same intensity level as that of the 2006 storm would happen in Year 1 (and the storm similar to the 2009 storm would happen in Year 3). It was further assumed that house reconstruction would take one year. The second option was that a similar storm as the 2006 event would happen in Year 2, and another one similar to the 2009 event would happen in Year 4. Using a progressive assumption that such 2006 and 2009 storm events would happen from Year 1 to Year 30 of the project lifetime ensured a complete view of what the overall economic returns would be in a range of occurrences. Whether they would happen earlier or later in the life

[8] This study did not include certain types of costs, such as the cost of deaths or injuries or the cost of social disruptions within a group or community. Storms lead to critical social disruptions, human causalities, and so forth; but because such costs are difficult to quantify, the researchers did not include them in the overall analysis.

of the investment would have a big impact on the returns to the risk reduction investment.[9] Meanwhile, the average case was calculated based on the results of each option.[10]

The results in Table 9 show that if the storms would happen very early in the project lifetime (i.e., a similar storm as the 2006 event would happen in Year 1 and another one similar to the 2009 storm would happen in Year 3), then the returns would be optimal (i.e., the best case). Conversely, if the storms would happen very late in the project lifetime (similar event as the 2006 storm would happen in Year 28 and another one like the 2009 event would happen in Year 30), then the results would be the worst (i.e., the worst case). This implies a progressive decrease in benefits depending on when the storm event would happen along the lifetime spectrum of the investment.

In the averaged case, the results show that IRR would be about 7.5% (i.e., much higher than the real discount rate of 4% in 2013). This implies that it would be preferable to invest in storm-resilient housing rather than to invest in a bank. The best case would take place when the storms happen very early in the project lifetime. Results of the averaged case in Table 9 show that NPV would be > 0; BCR, > 1; and IRR, > 4% (i.e., real discount rate in 2013). This implies that the economic return of investing in storm-resilient housing would be desirable. Note that this is a conservative result based on the assumption that only two storms would occur in the next 30 years.

It is critical to determine at what period during the lifetime of the house the turning or breakeven point would be (i.e., breakeven case: from a positive NPV to a negative one). The analysis results show that the breakeven case would occur if a similar storm as the 2006 event would happen in Year 17 and another storm as the 2009 event would happen in Year 19 (Figure 16). Meanwhile, varying interest rates were used to test the sensitivity of the results. Figure 17 shows the full range, from interest rates equal to 2%–10% and BCR results ranging from 2.05 to 1.13, respectively.

Table 9. Projected economic returns of Scenario 1, three-compartment house

Indicator	Best Case	Worst Case	Averaged Case
NPV ('000 VND)	84,808.50	–21,942.25	14,059.99
IRR (%)	268.00	–	7.50
BCR	4.91	0.08	1.73

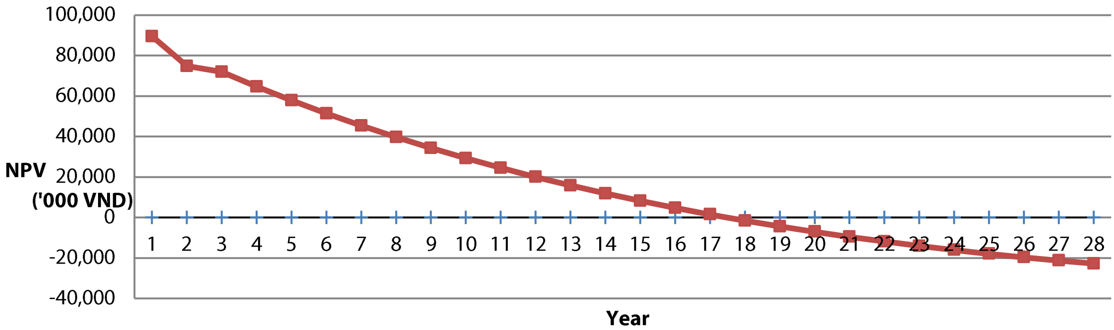


Figure 16. Breakeven case (three-compartment house)

[9] Any loss that would happen later in the investment life would account for a small benefit.

[10] Sample calculations of NPVs for all individual options for three-compartment house are presented in Appendix 3.

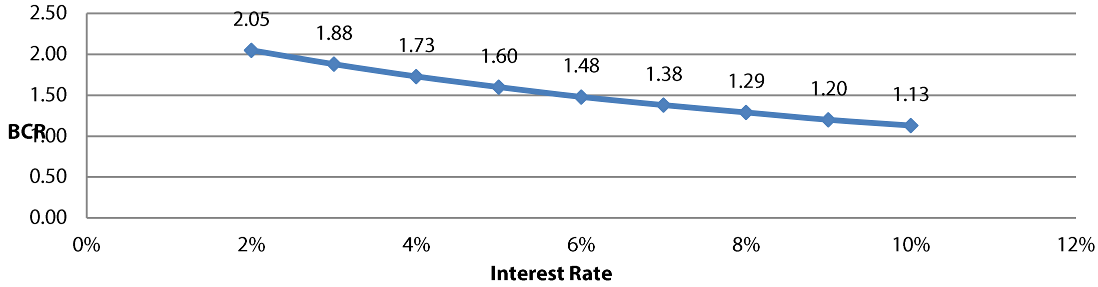


Figure 17. Scenario 1 BCRs with different interest rates (three-compartment house)

Scenario 2: Increased intensity of major events. In the "increased intensity of major events," the amount of damages incurred would increase over the lifetime of the house. In other words, it is assumed that a Category 11 storm, similar to the 2006 event, can occur twice in the next 30 years. Table 10 reports the projected return on investment of storm-resilient housing; the BCR results of the sensitivity analysis are presented in Figure 18.

Results of Scenario 2 show that the base case IRR would be about 9.5% (compared to 7.5% in Scenario 1), and the breakeven case would occur in Years 19 and 21 of the housing lifetime. In other words, the returns of Scenario 2 would be higher than that in Scenario 1. Thus, taking the impact of climate change into account in house building would result in higher returns on investment.

Table 10. Projected economic returns of Scenario 2, three-compartment house

Indicator	Best Case	Worst Case	Averaged Case
NPV ('000 VND)	117,135.95	−21,942.25	24,604.24
IRR (%)	279.00	–	9.50
BCR	6.37	0.08	2.23

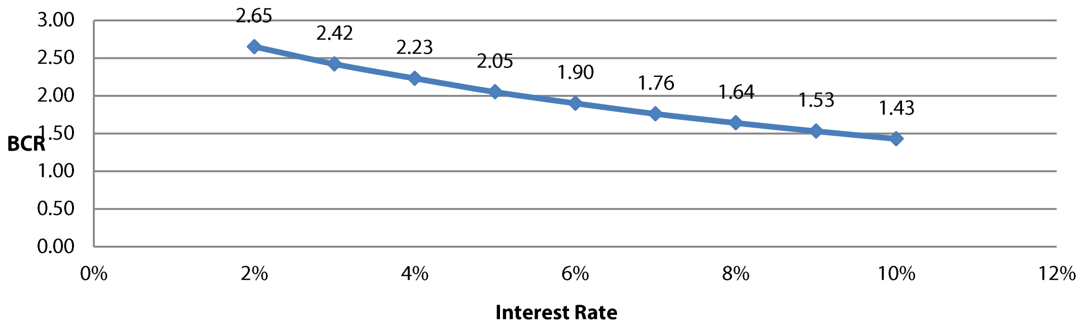


Figure 18. Scenario 2 BCRs with different interest rates (three-compartment house)

5.2.2 Tube housing

Scenario 1: Historical frequency and intensity of major events. The NPV, IRR, and BCR were calculated using storm events occurring at different time periods over the lifetime of the house. Table 11 shows that in the averaged case, the IRR would be equal to about 6.5% (i.e., higher than the real discount rate of 4% in 2013). This implies that it would be preferable to invest in storm-resilient housing than to invest in the bank (note that this is a conservative result based on the assumption that only two storms would occur in the next 30 years). The best case would take place if the storms happen very early in the project lifetime; the worst case would occur if the storms happen very late in the housing lifetime (Table 11).

In this scenario, the turning point or breakeven case would occur if a similar storm as the 2006 event would happen in Year 15 and another storm similar to the 2009 event would happen in Year 17 (Figure 19), at which point NPV becomes negative. Figure 27 shows the full range of sensitivity testing, using interest rates 2%–10% and BCR results ranging from 1.57 to 0.87, respectively.

Table 11. Projected economic returns of Scenario 1

Indicator	Best Case	Worst Case	Averaged Case
NPV ('000 VND)	82,980.66	–31,274.44	10,695.07
IRR (%)	188.00	–	6.50
BCR	3.75	0.06	1.33

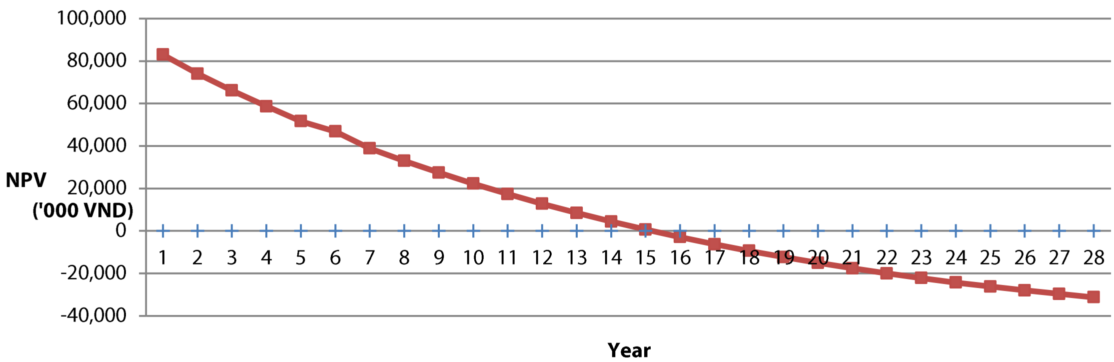


Figure 19. Breakeven case (tube house)

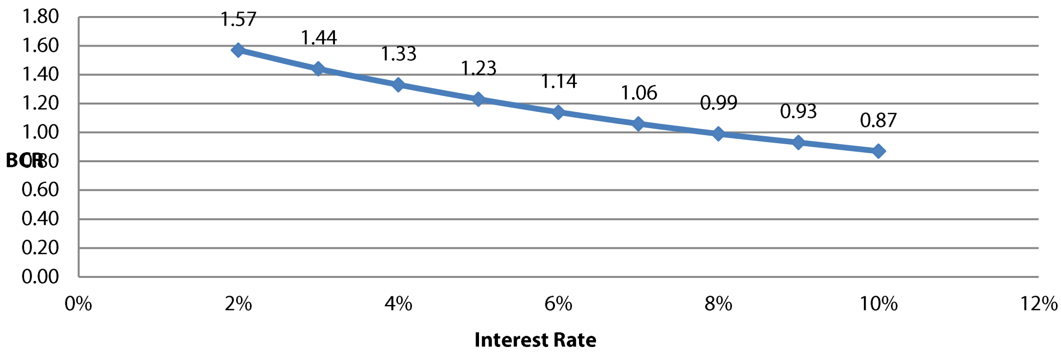


Figure 20. BCRs with different interest rates (tube house)

Scenario 2: Increased intensity of major events. In the "increased intensity of major events" scenario, it was assumed that a Category 11 storm (similar to the 2006 storm event) would occur twice in the next 30 years. The projected returns on investment of a storm-resilient tube house are reported in Table 12; the BCR results of the sensitivity analysis are presented in Figure 21.

The results of Scenario 2 in Table 12 show that the averaged case IRR would be 8.5% (compared to 6.5% in Scenario 1), and the breakeven case would occur in Years 17 and 19. In other words, the returns of Scenario 2 were projected to be higher than that in Scenario 1. Thus, taking into account the impacts of climate change in house building would result in higher returns on investment.

Table 12. Projected economic return of Scenario 2, tube house

Indicator	Best Case	Worst Case	Averaged Case
NPV('000 VND)	118,077.71	-31,274.44	23,608.28
IRR (%)	201.00	-	8.50
BCR	4.89	0.06	1.72

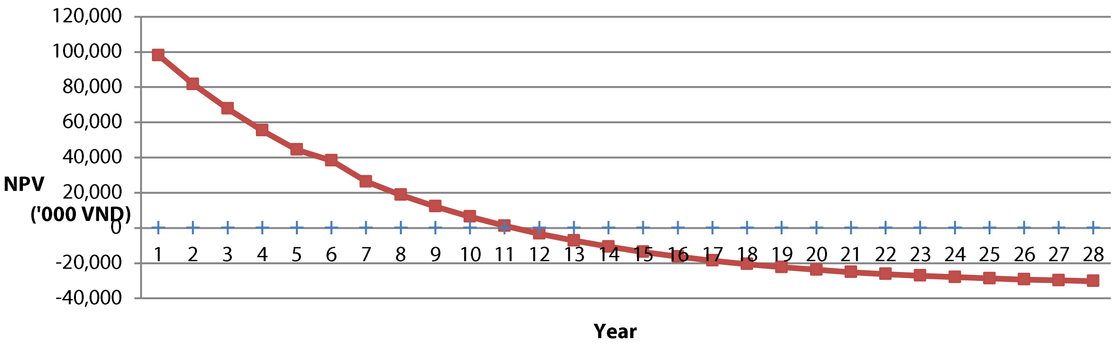


Figure 21. Scenario 1: Breakeven case (tube house)

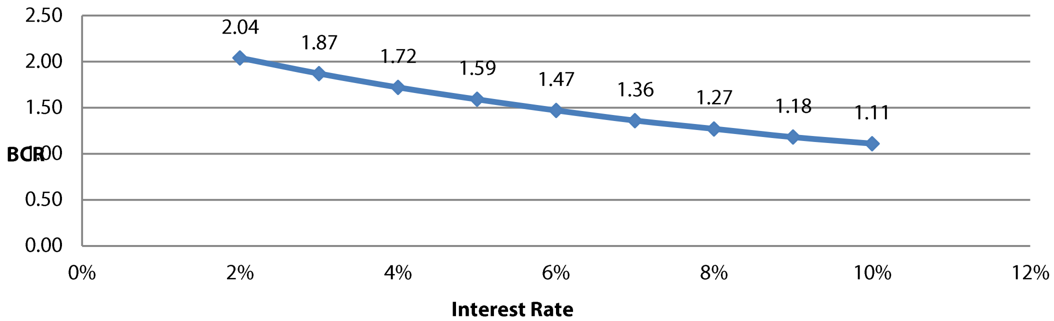


Figure 22. Scenario 2: BCRs with different interest rates (tube house)

5.3 Scope and Limitations

This paper has some limitations in providing a fully integrated CBA as follows:

1. *Small storms were excluded from the analysis.* Many storms have hit TTH in the past 30 years, but only two storms (Xangsane in 2006 and Ketsana in 2009) were used in the analysis. This is because these two storms were the largest in the past quarter century, causing significant damages to the houses in the province. Other smaller, more frequent storms were not considered because these smaller events often do not damage housing stocks significantly.
2. *Intangible costs were likewise excluded from the analysis.* In the quantitative CBA—that is, the estimation of damage costs per household—the study did not include intangible costs, such as cost of social disruptions within a group or community. The destruction of many houses in a community would likely lead to critical social disruptions, in which social relations among community members and local cultural values can be threatened or destroyed. Another form of intangible costs is the human casualties caused by storms. Although this is a terrible loss to families, it is very difficult to convert human loss into economic costs. As this study is intended to deal with the economic aspects of storm-resilient housing, only those damages that can be converted into economic costs were included, while those that relate to psychological issues such as trauma, peace of mind, and safety concerns were not considered in the quantitative CBA. Likewise, environmental benefits were not taken into account in this study.

3. *Exclusion of multiple hazards.* This study is limited to single-hazard analyses (i.e., storm and storm-related floods). If the analysis further took into account multiple hazards such as floods, droughts, and earthquakes, the costs might increase significantly.
4. *Intensity thresholds issue.* In this study, the capacity of the storm-resilient houses to withstand a storm was pegged at intensity 11–12 on the Beaufort scale. This means that this type of houses may not be able to withstand storms stronger than 11–12 intensity[11] in the future.
5. *The cost of storm-resilient housing is case-specific.* The cost of storm-resilient houses was estimated based on the assessments given by the DRR experts, built-environment professionals, and local builders consulted during the course of the research; and based on the cyclone-resistant housing models provided by DWF. Thus, the costs are case-specific. The costs associated with this housing model could vary depending on the quality of materials, design features, floor area of the house, and so forth. In reality, local people can build a larger or smaller house, use a different quality of materials, employ different design features, and so forth.
6. *The return on investment is uncertain.* Due to variations in housing design features, degree of storm intensity, discount rates used, and future climate uncertainty, the projected returns on investment in the storm-resilient housing presented in this study carry a high degree of uncertainty. This may limit the accuracy of the research results.
7. *Flood hazards were excluded in the CBA calculations.* There are two main reasons why this study did not include the flood risks in the CBA calculations.

   First, the impacts of flood on the local communities in Thua Thien Hue province and in larger Central Vietnam have not been as serious as that of the recent storms. The protective measures that the local people have been using to reduce the damages due to recent floods are still effective; whereas the DRR measures employed by the local people to protect their homes are no longer effective. This is because the recent typhoons have been stronger and more unpredictable (e.g., typhoon Nari and Wutip in 2013).

   The second reason is the technical structural difference between storm and flood risk reduction. Although there are many options for structural reinforcement for storm risk reduction (e.g., using continuous beams, strong bracings, connections, short roof-eaves, separated veranda, or balcony), there seem to be only one option for flood protection—raising the house's floor or subfloor.

6.0 CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Conclusions

Central Vietnam experienced a strong storm in 2006 when storm Xangsane made landfall. The storm devastated the local communities and destroyed thousands of houses. It is projected that future storm would be more intense in Central Vietnam (IMHEN 2013). In addition, the region frequently experiences floods, and it is projected that climate change would intensify the flood risk in the future (IMHEN 2013) as the area's growth and settlement tend to occur in low-lying areas.

Housing construction in Central Vietnam has undergone great changes as a result of economic improvement in recent years. More durable and costly materials are now being used in housing repair and construction instead of traditional materials. However, the lack of guidance and instruction from professionals and authorities has resulted in houses that are more vulnerable to flooding and storms.

The results of the CBA in this study showed that the returns on investment in storm-resilient houses are positive and high. This implies that investing in storm-resilient housing can be economically viable. The results also showed that the returns would highly depend on the year when a storm event would take place. If an event would happen early in the housing lifetime, returns on the investment would be positive. The breakeven cases in both the tube and the three-compartment houses would take place if the storms

[11] An example of this would be if super-storm Haiyan had made landfall in Central Vietnam.

would happen in the middle of the housing lifetime. Likewise, if the impacts of climate change would be taken into account, the return on investment would be higher.

From a private perspective, positive returns encourage households to invest in housing resilience. Autonomous adaptation has been occurring and has generally been driven by individual households; these have actually resulted in substantial investments to increase the resilience of houses. The stakeholders who have been involved in local housing constructions are individual household owners, architects, and masons. Furthermore, most of the money being brought into such investments is from individuals with relatively little input from the formal banking system. In other words, the government has little role in these local housing constructions. However, government action could greatly enhance the effectiveness of autonomous adaptation behaviors through targeted financial mechanisms (such as micro-credit), design support, improvements in other essential urban systems, and wider urban planning processes. Institutional shifts, such as building codes and land-use zoning, could also enhance the effectiveness of autonomous behavior of individual households and reduce the externalities that such behavior entails.

6.2 Policy Implications

This study investigated storm resilient-housing that are being undertaken by individual households. Thus, the implications of the results for local people living in storm-prone areas of Central Vietnam are first examined in this section. Then, the implications for public sector interventions are discussed.

6.2.1 Implications for individual households

The results of this study showed that the returns on storm-resilient housing investment are positive and high. This implies that local households should prioritize investing in such endeavor. However, positive returns are a necessary, but insufficient, condition to justify investing in storm-resilient housing. Individual households have budget constraints, and the additional cost of building a storm-resilient house (instead of a traditional house) prevents local households from making that investment. Another consideration is that individual households may expect their governments to provide post-disaster assistance to repair the damages to their homes. If this is the case, they will have an even lower financial incentive to invest in storm-resilient housing.

There is extensive evidence that individuals can be myopic in the sense that they have short-time horizons when planning for the future, especially if they do not expect to benefit from the investment. People with low incomes are often myopic, given that they often face extremely pressing and immediate problems (Kunreuther, Meyer, Michel-Kerjan 2010); disaster is not as important as meeting the basic needs of subsistence. In addition, many local household owners who reside in hazard-prone communities tend to dismiss the risk as negligible until after a disaster occurs. These barriers limit individual households' capacity to invest in storm-resilient housing.

6.2.2 Implications for public policy

Encouraging individual investment. The CBA results show that storm-resilient housing has high BCRs. In order to encourage individuals to invest in storm-resilient housing, the government should consider offering assistance to households that agree to undertake appropriate climate-resilient housing measures. This may take the form of technical assistance, direct subsidies, or low-interest loans.

For example, in 2012, the government approved the pilot program for flood-resilient housing for poor households in 14 provinces in North Central Vietnam (Decree No. 716). In this pilot program, 40,000 households will be directly supported with cash (about VND 10–12 million), as well as a loan with a low interest rate (VND 15 million) per household. However, this program does not take into account storm should have in order to increase housing resilience for the poor.

Note that the availability of disaster assistance distorts property owners' incentives, leading to more risky activities and fewer loss-limiting measures (Harrington 2000). However, in the case of low-income households in Central Vietnam (where households are often affected by floods and storms) when the disasters had happened, the government spent a large amount of resources (in cash or in kind) to support or compensate those households affected by the calamity. After the Xangsane storm in 2006 hit the study sites, each collapsed house was provided with about VND 5 million (about USD 300). Therefore, even though disaster assistance may contain certain disadvantages, in this case, it is more cost-effective for the government to provide households with disaster assistance via insurance subsidies as a risk management tool rather than providing post-disaster support or compensation. This means that disaster assistance is still an effective way to reduce damage costs to households affected.

Micro-insurance policy. Micro-insurance mechanisms have been viewed as an efficient and reliable risk management tool to encourage households in developing countries to adopt DRR measures (Linnerooth-Bayer, Hochreiner-Stigler, and Mechler 2012; World Bank 2012). Index-based disaster insurance plans, such as those for flood and drought, have been widely applied in low-income countries (World Bank 2012), but storm insurance is still new.

Storm insurance policies were pioneered in the Philippines in 2009 to protect Filipino farmers against storm-related losses (IFC 2013). This would seem to have relevant application in Central Vietnam where several storms hit the region every year. Vietnam has created a subsidized public-private partnership for agricultural crop, livestock, poultry, and aquaculture insurance; the government has promoted this program by providing premium subsidies to farmers from 2011 to 2013 (World Bank 2012). Therefore, for future DRR initiatives, storm insurance policies could be an appropriate option.

Investment in public projects for disaster risk reduction. Investments in projects, such as public shelters or improved early warning systems, could also help the local people to protect their assets and their lives.

Public shelter is a popular solution to enhance local resilience to floods in rural areas in Central Vietnam. The first model of public shelter was built in Hoa Quy, Da Nang City in 2006 with a concrete two-storey house and an area of 300 square meters. The public space not only serves as shelter for local people during flood and storms, but also as a place for living activities and meetings of local communities. There is a kitchen, toilet, power generator, beds, and other living necessities for sheltering about 300 people for about a week. This type of shelter is extremely effective in dealing with floods in low-lying areas because public buildings in general do not exist. However, in recent years under the government's reallocation program, many apartment buildings have been built for relocation of households located in low-lying areas. In addition, due to rapid economic growth, more safe buildings (e.g., schools, health care centers, and public buildings) with permanent structure are being built in these areas. Therefore, many public shelters in Central Vietnam are abandoned especially during off-flooding seasons.

LITERATURE CITED

CECI (Center for International Studies and Cooperation). 2011. Framework on community-based disaster risk management in Vietnam. CECI, Montreal, Canada.

Chantry, G. and J. Norton. 2008. Vaccinate your home against the storm: Reducing vulnerability in Vietnam. Open House International. 33(2): 26–31.

CIA World Fact Book. 2013. Inflation rate for Vietnam. http://www.indexmundi.com/g/g.aspx?c=vm&v=71 (Retrieved 20 December, 2013).

Do T.N. and J. Bennett. 2005. An economic valuation of wetlands in Vietnam's Mekong Delta: A case study of direct use values in Camau province. Environmental Management and Development Occasional Paper No. 8. Asia Pacific School of Economics and Government, Australian National University, Canberra.

DWF. 2011. Atlas of housing: Vulnerability and safe measures. DWF, Vietnam.

GSO (General Statistics Office). 2009. Migration and urbanisation in Vietnam: Conditions, trends, and differences. GSO, Hanoi, Vietnam.

———. 2011. Statistical yearbook of Vietnam. GSO, Hanoi, Vietnam.

Harrington, S.E. 2000. Rethinking disaster policy regulation. Regulation. 23(1): 40–46.

IFC (International Finance Corporation). 2013. International Finance Corporation and partners to launch storm insurance for Filipino farmers. http://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/industries/financial+markets/news/ifc+and+partners+to+launch+storm+insurance+for+filipino+farmers (Retrieved 13 November 2013).

Iglesias, G. 2006. Promoting safer housing construction through CBDRM: Community-designed safe housing in post-Xangsane Da Nang City. Safer Cities. 19: 2–8.

IMHEN (Institute of Meteorology, Hydrology, and Environment). 2013. High-resolution climate projections for Vietnam (Regional Summary). IMHEN, South Central Vietnam.

Khan, F.; M. Moench; S.O. Reed; A. Dixit; S. Shrestha; and K. Dixit. 2012.Understanding the costs and benefits of disaster risk reduction under changing climate conditions: Case study results and underlying principles. Institute for Social and Environmental Transition-International, Bangkok, Thailand.

Kobayashi H.; Duc T.T.; and Tanaka U. 2012. Housing conditions of a lagoon village in a flood-prone area of Central Vietnam. Journal of Asian Architecture and Building Engineering. 11(1): 79–85.

Kunreuther, H.; M.J. Meyer; and E. Michel-Kerjan. 2010. Strategies for better protection against catastrophic risks. Working Paper No. 2007-09-14. Risk Management and Decision Processes Center, The Wharton School, University of Pennsylvania, PA.

Linnerooth-Bayer; J. S. Hochreiner-Stigler; and R. Mechler. Mechanisms for financing the cost of disasters. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Mechler, R. 2005. Cost-benefit analysis of natural disaster risk management in developing countries. Deutsche Gesellschaft fur Technische Zusammenarbeit (GIZ), Eschborn, Germany.

Nguyen H.H. 2002. Risk assessment and management for a sustained shelter delivery system in Vietnam. Proceedings of the Workshop on Safer Shelter in Vietnam, 4–5 September, 2002, Hanoi, Vietnam. Asian Disaster Preparedness Center, Bangkok, Thailand. 59–74.

Nordhaus, W.D. 2006. The economics of hurricanes in the United States. NBER Working Paper Series Working Paper No. 12813. National Bureau of Economic Research, Cambridge, MA.

PSFC (Provincial Committee for Flood and Storm Control). 2008. Disaster data in Thua Thien Hue. http://pclb.thuathienhue.gov.vn/ (Retrieved 15 January, 2014).

Pearce, D.; G. Atkinson; and S. Mourato. 2006. Cost-benefit analysis and the environment: Recent developments. Organisation for Economic Co-operation and Development, Paris, France.

Phong, T. and Tinh B.D. 2010. Housing sector considerations in disaster risk reduction and climate change adaptation. R. Shaw, J. Pulhin, and J.J. Pereira (eds.) *In* Climate change adaptation and disaster risk reduction: Issues and challenges. Emerald Group Publishing Limited, Bradford, United Kingdom. 291–302.

Pompe, J.J. and J.R. Rinehart. 2008. Mitigating damage costs from hurricane strikes along the southeastern US coast: A role for insurance markets. Ocean & Coastal Management. 52(12): 782–788.

Reed, S.O. and P. Thinphanga. 2012. New risk and risk transfer: Climate and urban development case studies from Vietnam and Thailand. Proceedings of Vietnam Cities Tomorrow: Action Today, Vietnam Urban Conference, 30 October, 2012, Hanoi, Vietnam. Ministry of Construction and Vietnam Urban Forum and Cities Alliance, Hanoi, Vietnam.

Sutter, D.; D. de Silva; and J. Kruse. 2009. An economic analysis of wind resistant construction. Journal of Wind Engineering and Industrial Aerodynamics. 97(3): 113–119.

Thang L.T.; Tue T.N.; Tung N.T.; Yen V.V.H.; Hien N.T.T.; Dat P.V.Q.; Toan L.T. and Thai T.V. 2013. Design proposal for climate-change resilient housing in the context of urbanisation. Vietnamese Journal of Architecture. 6: 38–41.

Thomas, T.; L. Christiaensen; Do Q.T.; and Trung L.D. 2010. Natural disasters and household welfare: Evidence from Vietnam. World Bank Policy Research Working Paper Series, Volume 2010. The World Bank, Washington, D.C.

Tinh B.D.; Tuan T.H.; Phong T.; The B.D.; and Tam B.T. 2010. Local vulnerability and adaptation to extreme climate events along the central coast of Vietnam. R. Shaw, J.M. Pulhin, and J.J. Pereira (eds.) *In* Climate change adaptation and disaster risk reduction: An Asian perspective. Emerald Group Publishing Limited, Bradford, United Kingdom. 393–416.

Tran P. and Bui D.T. 2010. Impact study on developing local capacity to reduce vulnerability and poverty in Central Vietnam. Development Workshop Vietnam/France, Lauzerete, France/Hue, Vietnam.

Tran T.A.; Tran P.; Tran H.T.; and K. Hawley. 2012. Review of housing vulnerability: Implications for climate resilient houses. Sheltering Series No. 1. Institute for Social and Environmental Transition-International (ISET-International) Vietnam, Hanoi, Vietnam.

Tran T.A.; Tran V.G.P.; Tran H.T.; and M. Mulenga. 2013. Community consultation for long-term climate resilient housing in Vietnam cities: A comparative case study between Hue and Da Nang. Asian Cities Climate Resilience Working Paper Series No. 2. International Institute for Environment and Development (IIED), London, United Kingdom.

Truong, D.D. 2011. Valuing the total economic values of wetlands in Ba Lat estuaries, Nam Dinh province. National Economics University, Hanoi, Vietnam. PhD dissertation.

TTH Provincial Government. 2013. Thua Thien Hue province, Central Vietnam. http://www.thuathienhue.gov.vn/en-us/Home/Detail/cid/D6E7F610-5757-467E-B384-94E7458D4286 (Retrieved 13 November, 2013).

Tuan, T.H. and S. Navrud. 2008. Capturing the benefits of preserving cultural heritage. Journal of Cultural Heritage. 9(3): 326–337.

World Bank. 2012. Advancing disaster risk financing and insurance in Asian member states: Framework and options for implementation (Vol. 1: Main report). The World Bank, Washington, D.C.

APPENDIX

Appendix 1. Economic Definitions

Discount rate. In economic calculations, future benefits are discounted in relation to current benefits to reflect the cost of capital. This is justified assuming that the current value of future benefits from investments would be compared to existing, secure investment alternatives for the same funds. Applying high discount rates expresses a strong preference for the present conditions, although it can potentially shift large burdens to future generations. The standard practice in developing countries is to assume a discount rate of 10%–12%; this is often an observed nominal market interest rate. However, in this study, the real interest rate (r) was used instead of the observed nominal market interest rate (n). Since the discount rate chosen is based on an observed nominal market interest rate (n), one should expect that this credit market anticipates some future level of inflation (i^*). To arrive at the appropriate real interest rate (r) for discounting purposes, one should choose estimates of expected inflation (i^*), and then use the expected relationship that $r \approx n - i^*$. If the rates of inflation are expected to vary over time, then one can estimate a series of real rates that are specific to each year or time period (t) where $(1 + n)t = (1 + rt)t \times (1 + it^*)t$. Then, solve for each rt.

Cost increase. Due to unforeseen price increases in labor and materials, one may assume that the cost of labor and materials increases by the same rate as that of inflation (which is measured by the consumer price index). However, this also goes in the benefits section (avoided damages). Therefore, cost increases on the cost and the benefit sides cancel each other out (and were thus not taken into account in this study).

Fragility decrease. In this study, it was assumed that the overall fragility of the house would decrease over time due to the increased density of housing structures. As population increases, so will housing density in urban areas. The new houses will create a denser environment (more structures) and will reduce the potential damage experienced by each household. On the average, the total assets of households will increase over time (resulting in an exposure increase); whereas density of houses will increase, resulting in a fragility decrease. These two assumptions cancel each other out and were not taken into consideration in the calculations.

Year of storm occurrence. Due to limited certainty of climate models to predict future storm frequency and intensity, the researchers assumed that storm events (e.g., 2006 and 2009 events) would occur at different time periods over the lifetime of the house. This ensured a complete view of what the overall economic returns would be in a range of occurrences.

Climate scenario. Two climate scenarios were presented: (1) the climate would stay the same and (2) climate extremes would increase. In the first scenario, it was assumed that the climate would stay the same over the next 30 years. In the second scenario, it was assumed that exposure and losses would increase annually due to increases in population and housing in TTH.

Sensitivity analysis. Several discount rates were used for the sensitivity analysis, including a low discount rate of 2% (as used by social housing programs) and a high discount rate of 10% (as used by local banks). Using a range of 2%–10% was useful in understanding the implications of the chosen rate.

Net present value (NPV). Costs and benefits arising over time are discounted and the difference were taken, which is the net discounted benefit in a given year. The sum of the net benefits is the NPV. A fixed discount rate was used in this study to represent the opportunity cost of using public funds for a given project. If the NPV is positive, then a project is considered desirable.

Benefit-cost ratio (BCR). The BCR is a variant of the NPV, with the benefits divided by the costs. If the ratio is > 1, then a project is considered to add value to society.

Internal rate of return (IRR). Whereas NPV and BCR use a fixed discount rate, this criterion calculates the interest rate internally. This represents the return on investment of the project. A project is rated to be desirable if the IRR surpasses the average return of public capital as determined beforehand (e.g., 4%, using real interest rate in 2013).

Construction cost. In this study, construction cost refers to the additional cost of resilient housing. This is the difference in the cost of resilient housing and the cost of nonresilient housing with the same floor area and at 2013 prices (see in Table 1). Table 1 below shows the estimation of construction cost for a three-compartment house.

Appendix Table 1. Sample cost estimation of a three-compartment house

COST ESTIMATION OF THREE-COMPARTMENT HOUSE (47.6m²)					
(Based on the market price of July 2013 in Thua Thien Hue Province)					
No	**Material**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Cement	kg	7,980.0	1,235	9,855,000
2	Sand (for mortar)	m³	3.4	60,000	204,000
3	Fine sand (for plastering)	m³	9.4	60,000	564,000
4	Stone 4–6	m³	2.8	240,000	672,000
5	Stone 1–2	m³	6.0	300,000	1,800,000
6	Brick 10 x 15 x 22 (six-hole brick)	viên	7,700.0	2,500	19,250,000
7	Stone blocks for foundation	m³	10.7	180,000	1,926,000
8	Steel wire Φ6	kg	107.0	16,200	1,733,000
9	Steel wire Φ8	kg	172.0	16,200	2,786,000
10	Steel bar Φ10 (for pillars)	cây	27.0	60,000	1,620,000
11	Steel bar Φ16 (for beams)	cây	5.0	80,000	400,000
12	Steel wire Φ4 (for con lươn on roof)	kg	7.0	16,200	113,000
13	Steel wire for binding	kg	10.0	17,500	175,000
14	Clay tile (22 tile per m²)	viên	1,960.0	12,950	25,382,000
15	Roof-top covering tiles	viên	30.0	18,000	540,000
16	Wood group 3 for roof purlins 8 x 8	m³	0.9	9,000,000	8,100,000
17	Wood for litô	m³	0.4	9,000,000	3,330,000
18	Wooden doors & windows (with latches)	m²	14.0	700,000	9,800,000
19	Sub-materials	đơn vị	1.0	1,000,000	1,000,000
20	Labor	m²	47.6	500,000	23,800,000
	SUBTOTAL				113,050,000
	Spare free (for unexpected arisen things)			5%	5,653,000
	TOTAL				**118,703,000**
Average cost per floor's square meter (m²)					**2,493,761**

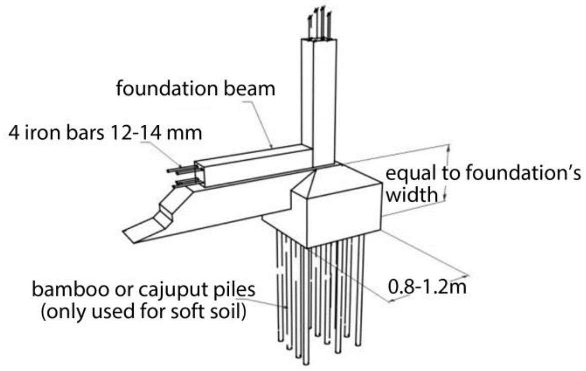
Operation and maintenance (O&M) cost. On the average, operations and maintenance occurs every five years. The research team assumed that 2% of total constructions costs equate to the average operations and maintenance costs incurred by a household.

Lifetime of house. 30 years

Appendix 2. Technical Details for Storm Resilient Construction

Foundation

Although storms do not directly impact the foundation, it helps the house to be more stable during storm events. The sink or movement of the foundation is the most common problem in housing, which is mainly because the foundation is laid on soft soil and lacks foundation bracing. For houses built on soft soil, bamboo or cajuput piles are added to the ground and under the foundation (Appendix Figure 1).

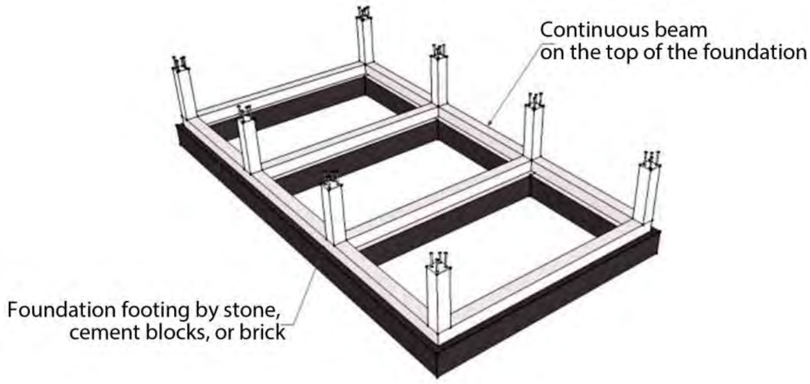


Appendix Figure 1. A DWF house rebuilt after storm Xangsane in Loc Vinh

Within "normal" ground conditions, there are several technical requirements, as follows:

- The width of each side of the pillar's foundation is 0.8–1.2 m.
- The depth of the pillars' foundation should be deep enough to anchor the building to the ground, frequently equal to or longer than the width of the pillar's foundation.

In building storm-resilient houses, there must be a reinforced concrete (RC) continuous beam, (known as the foundation bracing) above the foundation footing (stone, brick, or cement-block) at the ground level. The height of this beam should be 80–150 mm, depending on the beam's position in the house. The beam's width is equal to the thickness of the walls above, usually 220 mm (Appendix Figures 2 and 3).



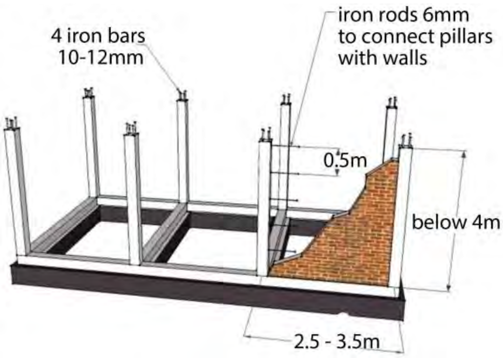
Appendix Figure 2. A DWF house rebuilt after storm Xangsane in Loc Vinh

Appendix Figure 3. A closed foundation of a new house found on site

For the foundation of the main structure of the house, the beam must be 150 mm high with four iron bars inside. For the foundation of the substructure, such as verandas, the beam can be 80 mm high with two iron bars. Iron bars used for this beam must have a diameter of 12–14 mm. Iron wires used for binding iron bars must have a diameter of 6 mm, with a maximum distance of 200 mm between them.

Walls

The RC pillars must have four iron bars inside, with a minimum diameter of 10 mm. The height of these pillars should not be higher than 4 m (Appendix Figure 4). The envelope or boundary walls must be thick enough (at least 150–220 mm). Bricks must be laid in a horizontal direction, especially for the six-hole brick commonly used in current housing construction. In addition, RC pillars must be added at an interval of 2.5–3.5 m, with two RC continuous beams at the foundation and door/window level.



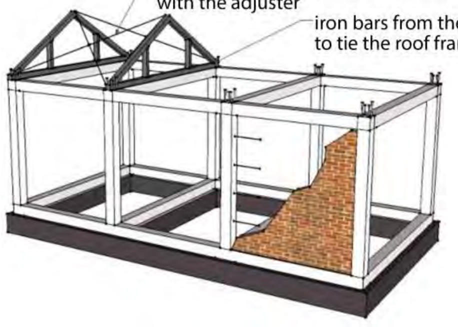
Appendix Figure 4. Technical details for storm resilience for the walls

To connect the walls to the RC pillars, there must be some iron rods with a length of 0.4–0.5 m to anchor the walls securely to the RC pillars. These rods must be placed in the RC pillar when pouring concrete at an interval of 0.5 m.

Roof

The roof frame must be securely attached to the house's structure, and the roof covering must be strongly tied to the roof frame. The roof frame can be steel, wood, or concrete, depending on the availability of materials and the economic capacity of each household. In the region of Hue, RC is commonly used for constructing the roof frame (Appendix Figures 5 and 6).

Likewise, there must be a number of iron rods with diameter of 6 mm or iron sheets on the beams to tie the roof frame to the main structure. In addition, there should be diagonal bracings at the roof's corners by iron wire 6 mm in diameter, with the adjuster (*tăng-đơ*) to tighten these iron wires.



Appendix Figure 5. A DWF house rebuilt after storm Xangsane in Loc Vinh

Appendix Figure 6. Strong roof connections in a DWF house visited

The roof covering can be made of clay tiles or corrugated iron sheets. The iron sheet for roof covering is cheaper than clay tiles. For the iron sheets used to cover the roof frame, the minimum thickness of the iron sheets should be 0.4 mm with the use of V steel bar (dimension 25 x 25 x 2 mm) to tie the roof coverings to the roof frames. The distance between the V bars should not exceed 2.5 m.

The roof cantilevers or roof-edges outside the walls should be placed in the concrete bars along the roof on the side of the gable walls. On the other side, its length should not exceed 20 cm and must have the gutter beneath it.

As the roof is sloping, it is necessary to have a ceiling. The roof's pitch must be 30°–45°.

Timber used for the roof frame and roof trusses should be classified as Group 2 according to 1997 Vietnam Building Code.

Doors and Windows

Doors and windows should be made of timber classified as Group 3. The door frame must be 100 x 80 mm, with the wooden panel for its underlying part (thickness of 2 cm) and iron sheets with thickness of 0.4 mm. For the windows, the window frames must be 40 x 80 mm. All doors and windows must have the bolts at the top and bottom and for the two-leaf door, there must be an additional Z-shaped iron sheet, as the latch, at the middle to tie the door to the walls by a wooden bar (Appendix Figure 7).


Appendix Figure 7. Strengthening wooden bars for door (left) and window (right) found in a DWF house visited in Loc Vinh

In short, addressing the above technical features is important to achieve a storm-resilient housing. The additional cost gained through using these safety standards in housing construction were considered in analyzing the costs and benefits of climate-resilient housing in comparison with a nonresilient one.

Appendix 3. Sample Calculations of NPVs, IRRs and BCRs for Rural House

Appendix Table 2. Key assumptions used in the cost-benefit analysis

Parameter	Estimate
Benefit (damage avoided) 2006 ('000 VND)	84,448.30
Benefit (damage avoided) 2009 ('000 VND)	42,427.69
Cost for resilient home-additional ('000 VND)	22,917.06
O&M cost ('000 VND)	458.34
Life time (years)	30.00
Discount rate (%)	0.04

Appendix Table 3. Calculation of Option 1: Best case scenario*

Parameter	Year										Total
	0	1	2	3	4	5	…	28	29	30	
Benefits		81,633.36**		38,184.92***			…				119,818.28
Discounted benefits	0.00	78,493.61	0.00	33,946.26	0.00	0.00	…	0.00	0.00	0.00	112,439.87
Costs							…				
Construction cost	–22,917.06						…				–22,917.06
O&M						–458.34	…				–2,291.71
Total costs	–22,917.06	0.00	0.00	0.00	0.00	–458.34	…	0.00	0.00	0.00	–25,208.77
Total discounted costs	–22,917.06	0.00	0.00	0.00	0.00	0.00	…	0.00	0.00	0.00	–22,917.06
Net discounted benefits	–22,917.06	78,493.61	0.00	33,946.26	0.00	0.00	…	0.00	0.00	0.00	89,522.81
Total benefits	–22,917.06	81,633.36	0.00	38,184.92	0.00	–458.34	…	0.00	0.00	0.00	94,609.52
NPV ('000 VND)					84,808.50						
IRR (%)					268.00						
B/C					4.91						

Notes: (1) A storm with the same intensity level as that of the 2006 event would happen in Year 1 and a storm similar to the Storm 2009 would happen in Year 3. (2) ** The 2006 storm: The benefits of foregone damages minus the salvage value of the house (= 84,448.30 – 84,448.30 / 30) (3) *** The 2009 storm: The benefits of forgone damages minus the salvage value of the house [= 42,427.69 – 3 * (42,427.69/ 30)].

Appendix Table 4. Calculation of Option 2

Parameter	Year										Total
	0	1	2	3	4	…	27	28	29	30	
Benefits			78,818.41		31,113.64	…					109,932.06
Discounted benefits	0.00	0.00	72,872.06	0.00	26,596.07	…	0.00	0.00	0.00	0.00	99,468.13
Costs						…					
Construction cost	–22,917.06					…					–22,917.06
O&M	–458.34					…					–2,750.05
Total costs	–23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	0.00	0.00	–25,667.11
Total discounted costs	–23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	0.00	0.00	–24,697.38
Net discounted benefits	–23,375.40	0.00	72,872.06	0.00	26,596.07	…	0.00	0.00	0.00	0.00	74,770.75
Total benefits	–23,375.40	0.00	78,818.41	0.00	31,113.64		0.00	0.00	0.00	0.00	84,264.95
NPV ('000 VND)					71,894.95						
IRR (%)					93.00						
B/C					4.03						

Note: Option 2 scenario is when a storm with the same level intensity as that of the 2006 event would happen in Year 2 and a storm similar to the Storm 2009 would happen in Year 4

Appendix Table 5. Calculation of Option 3

Parameter	Years										Total
	0	1	2	3	4	….	27	28	29	30	
Benefits			78,818.41		31,113.64	….					109,932.06
Discounted benefits	0.00	0.00	72,872.06	0.00	26,596.07	….	0.00	0.00	0.00	0.00	99,468.13
Costs						….					
Construction cost	−22,917.06					….					−22,917.06
O&M	−458.34					….					−2,750.05
Total costs	−23,375.40	0.00	0.00	0.00	0.00	….	0.00	0.00	0.00	0.00	−25,667.11
Total discounted costs	−23,375.40	0.00	0.00	0.00	0.00	….	0.00	0.00	0.00	0.00	−24,697.38
Net discounted benefits	−23,375.40	0.00	72,872.06	0.00	26,596.07	….	0.00	0.00	0.00	0.00	74,770.75
Total benefits	−23,375.40	0.00	78,818.41	0.00	31,113.64	….	0.00	0.00	0.00	0.00	84,264.95
NPV ('000 VND)					69,163.29						
IRR (%)					57.00						
B/C					3.91						

Note: Option 3 is when a storm with the same intensity level as that of the 2006 event would happen in Year 3 and a storm similar to Storm 2009 would happen in Year 5.

Appendix Table 6. Option 28: Worst case scenario

Parameter	Year											Total
	0	1	2	3	4	…	26	27	28	29	30	
Benefits						…			5,629.89		0.00	5,629.89
Discounted benefits	0.00	0.00	0.00	0.00	0.00	…	0.00	0.00	1,877.44	0.00	0.00	1,877.44
Costs						…						
Construction cost	−22,917.06					…						−22,917.06
O&M	−458.34					…						−2,750.05
Total costs	−23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	0.00	0.00	0.00	−25,667.11
Total discounted costs	−23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	0.00	0.00	0.00	−24,697.38
Net discounted benefits	−23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	1,877.44	0.00	0.00	−22,819.94
Total benefits	−23,375.40	0.00	0.00	0.00	0.00	…	0.00	0.00	5,629.89	0.00	0.00	−20,037.22

Note: The worst case is is when a storm with the same intensity level as that of the 2006 event would happen in Year 28 and a storm similar to Storm 2009 would happen in Year 30.

Appendix Table 7. The average case

Parameter	Estimate
NPV ('000 VND)	14,059.99
IRR (%)	7.50
BCR	1.73

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