SHELTERING FROM A GATHERING STORM

TYPHOON RESILIENCE IN VIETNAM

Sheltering From a Gathering Storm: Typhoon Resilience in Vietnam

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LIST OF ACRONYMS

ACCCRN Asian Cities Climate Change Resilience Network

BCR benefit-cost ratio

CBA cost-benefit analysis

CCFSC Central Committee for Flood and Storm Control

DRR disaster risk reduction

IMHEN Institute of Meteorology, Hydrology, and Environment

IRR internal rate of return

NPV net present value

SLD shared learning dialogue

VND Vietnamese dong

Da Nang is affected by many types of climate hazards, including typhoons, floods, drought, coastline erosion, landslides, and so forth, and the risk of such hazards is increasing as a consequence of global climate change.

Photo: Red Bridge, 2013

KEY POINTS IN BRIEF

1 Da Nang city is undergoing rapid change.
Located in Central Vietnam, the city of Da Nang is experiencing rapid urbanization and development.

2 Greater economic resources for construction are not creating safer houses.
As a result of economic improvement after the Reform policy in 1986, local households have more economic resources for investing in housing construction. Families now tend to use more durable and costly materials instead of traditional ones for housing repair or construction. However, without integrating appropriate safety measures for disaster risk reduction (DRR), improper construction practices with new materials can lead to greater damage when a storm hits.

3 Housing remains climate vulnerable despite DRR measures.
In recent years, floods and storms have caused extensive damage and losses to local communities despite great efforts by local governments and agencies to implement DRR. Housing is one of the most vulnerable sectors to climate extremes, with typhoons causing the greatest impact among climate hazards.

4 Typhoon safety measures are lacking.
Local households have adapted to living with floods, effectively adopting various autonomous measures to prevent and mitigate their impact. However, households still lack effective measures to withstand typhoon impacts, which greatly affect the poor and low-income groups.

5 Typhoon and extreme rain event intensity is projected to increase.
Results of the climate analysis show increasing flood frequency and severity in the city during extreme rain events, which is compounded by rapid development. Climate change will increase the intensity of rain events in and around Da Nang. Projections on climate change suggest that typhoon intensity is likely to increase, whereas typhoon frequency varies among climate models.

6 Design competition produced innovative construction models.
The Resilient Housing Design Competition, hosted in Central Vietnam to identify innovative designs to improve typhoon resilience, presented key adaptation options, both at the level of individual households and local neighborhoods, including site planning, building design, and construction technology.

7 New home construction remains preferred option.
Qualitative evaluation and ranking alternative options show that communities prefer building new houses over other options (e.g., repairing damaged housing or moving to public shelters).

8 Investment in resilience measures can be cost-effective.
Cost-benefit analysis (CBA) results show that the return on investment in typhoon resilient housing is positive when typhoon events occur early in the lifetime of the house.

9 Policy interventions could address resistance to adopting resilience measures.
Even though the economic returns on investing in a typhoon resilient shelter are high, households still might choose not to invest in resilient features. Policy interventions could encourage adoption of DRR measures by providing subsidized loans, promoting micro-insurance policies, adopting multi-hazard resilient construction, improving awareness of at-risk households and communities and stimulating local economies, bridging the gap between at-risk low-income groups and in-field professionals, and applying safety-related codes and criteria to local construction.

1. INTRODUCTION

1.1 Overall Context

Da Nang is the most dynamically developed city of Central Vietnam and is experiencing rapid economic development and urbanization. The city's gross domestic product growth rate is always one of the highest in the country and has reached over 12.4% in recent years. The annual population growth rate in Da Nang is 3.48%; the population is expected to reach 1.2 million in 2020 and 1.5 million in 2030, with an estimated urban population of 82% and 84%, respectively (Da Nang Urban Planning Institute, 2012). Located on the South Central Coast in the tropical storm belt, Da Nang experiences annual catastrophes. The city is characterized by a sloped topography from west to east, with many mountain ranges, short rivers, deltas, and coastal areas, which creates a diversified ecosystem and perhaps one of the most disaster-prone regions in Vietnam. As a coastal city, Da Nang is affected by many types of climate hazards, including typhoons, floods, drought, coastline erosion, landslides, and so forth, and the risk of such hazards is increasing as a consequence of global climate change.

The most dangerous hazards for Da Nang are storms (tropical lows and typhoons) and floods. The city is impacted by three to five storms[1] per year. Storms hit this city from May to December and are followed by long-lasting rains and inundation floods (Asian Cities Climate Change Resilience Network [ACCCRN], 2010). In recent years, strong storms and floods have caused critical damage and losses to local communities and have destroyed thousands of houses (e.g., flood in 1999, typhoon Xangsane in 2006, typhoon Nari in 2013) despite great efforts by local governments and agencies toward DRR. According to the Vietnam Central Committee for Flood and Storm Control (CCFSC), 80%–90% of the population is affected by floods and storms. As reported by the national government, housing is one of the sectors[2] most vulnerable to climate extremes (Ministry of Natural Resources and Environment, 2008). Typhoons exhibit the greatest impact on housing as compared to other climate hazards (Nhu, Thuy, Wilderspin, & Coulier, 2011).

After the Reform (*Đổimới*) policy in 1986, households began to use new materials (cement blocks, steel bars, fired bricks, or corrugated sheeting) in their housing construction instead of traditional materials (timber, bamboo; Norton & Chantry, 2008) but frequently without using safety-related measures (Tinh, Tuan, Phong, The, & Tam, 2011). This failure has generated a so-called twofold source of vulnerability (Norton & Chantry, 2008) by which the improper use of new materials combined with a lack of knowledge unexpectedly leads to a higher level of risk; when a storm hits, families are more vulnerable and the result is greater damage. Over 70% of houses built during this period did not incorporate typhoon resistant features; flat roofs were constructed, limited attachments between building elements were implemented, and structural bracings were lacking (Norton & Chantry, 2008). In addition, houses in low-lying areas lack flood protection features; for example, they lack upper floors for safekeeping valuables during floods or have hard and heavy roofs that are difficult to open for escape. Local communities and households have a history of living with floods and have adopted various autonomous measures to effectively prevent and mitigate the impact of floods (Tuan & The, 2013). However, in dealing with extreme climate hazards like typhoons, local communities and households are still lacking effective adaptation measures, especially in peri-urban and hazard-prone areas (near the river, near the sea, etc.), with poor and low-income groups impacted the most.

This research focuses on typhoon resilient housing measures. The main objective of this research is to investigate the performance of typhoon resilient housing through an economic perspective, which compares the costs and benefits of typhoon resilient housing. This research tests the hypothesis that applying principles related to typhoon resilience to housing construction has a positive economic return for households in Da Nang city.

1.2 Key Stakeholders and Policies

In Vietnam, to effectively prevent and mitigate the impact of storms and floods, agencies have been established at different administrative levels and in different sectors and locales. At the national level, the CCFSC is responsible for assisting the government in the establishment and implementation of the annual flood and storm preparedness solutions and plans. In the provinces, districts, and communes, People's Committees establish local committees for flood and storm control (CFSCs). The latter are responsible for

TABLE 1

KEY STAKEHOLDERS INVOLVED IN THE STUDY

	Government	Civil societies and mass organizations	Private sector	At-risk communities
City level	People's Committee Department of Construction Climate Change Coordination Office	Women's Union Fatherland Front Unions Architecture associations Universities, faculties, and research institutes	Central Vietnam Architecture Consultancy TT-Arch Company	
Ward level	People's Committee	Women's Union		
Households			Local builders	Poor and vulnerable households

helping their respective People's Committee to build and implement flood and storm protection measures in their particular area. Line ministries and central authorities have also established sector CFSCs to handle flood and storm preparedness and mitigation measures.

Key Stakeholders

Key stakeholders involved in this study include poor and climate vulnerable households in "at-risk" communities, Da Nang governmental agencies (such as the People's Committee, the Department of Construction, and the Coordination of Climate Change Office), civil societies (such as the Women's Union, the Fatherland Front, and the Architecture Association), universities and faculties of architecture in Da Nang and surrounding cities, and consulting companies in the field of construction and design (see Table 1).

Policies and Programs

At the national level, two key documents address DRR in all sectors of the country, including housing, through general guidelines and principles. The first document is the *National Strategy for Natural Disaster Prevention, Response and Mitigation to 2020*, released in 2007, with its key goal being to minimize damage and loss of human life and property. The second document is the *National Target Program to Respond to Climate Change*, released in 2008, with a focus on issues related to climate change. These two documents highlight the importance of disaster mitigation measures for residential housing in disaster-prone regions of the country, especially in Central Vietnam where floods and typhoons are increasing in number and severity. However, these documents play the role of top-down direction for the promulgation of building codes and regulations at lower levels in provinces and cities. Thus, they view DRR in macro terms—that is, without specific strategies or solutions for each sector or region at the local level. Because of this, responses to local needs, local contexts, and the capacity for disaster resistant housing are inadequately addressed in these two documents.

In Da Nang, city planning has taken DRR into consideration through building codes. For example, buildings close to the sea or a river must have a ground floor level higher than the 100-year flood level. Building permits are required and granted to households if the house floor area is over 250 m^2 and the building height is more than two stories. However, houses with a floor area less than 250 m^2 are not required to obtain a permit, even though these are the most vulnerable types of housing. This results in a lack of checks against safety-related standards. In addition, there is inadequate oversight by local authorities (i.e., no policies or legal framework) to force households to follow safe construction practices apart from advising or encouraging them to do so.

Dr. Phong Tran, Technical Lead of ISET-Vietnam, explains the process of building typhoon resistant housing at the meeting with Women Union staff.

Photo: Tho Nguyen, May 2012

1.3 Research Process

The research process involved five phases, as described here.

Phase 1	Phase 2
Defining the methodology.	**Assessing and gathering data.**
The initial phase included building and finalizing the research method and work plans, identifying research outcomes, and defining a set of indicators for the research. This involved the collaboration of experts from the Institute for Social and Environmental Transition (ISET)-International, Hue University (Vietnam), and the Gorakhpur Environmental Action Group (India).	The research team organized field visits to Da Nang to meet with city partners (the Women's Union, CFSC, universities, etc.) and collect relevant data, such as city level damage data, climate hazard data, and so forth. In addition, the team joined with ISET-International's experts to build an event frequency model for creating climate scenarios. Rainfall data and storm data were collected and linked to historical events to create probability projections.

Mrs. Phan Thi Lan —owner of a storm resistant house shares her satisfaction of her house with Dr. Phong Tran and Ms. Ngo Thi Le Mai from ISET, and Ms. Do Thi Kim Linh, Head of Da Nang's Women's Union.

Photo: ISET-International, May 2012

Phase 3	Phase 4	Phase 5
Contextualizing the study site.	**Building the solutions.**	**Analysis of results.**
The research team organized a series of shared learning dialogues (SLDs) with different related stakeholders, assessed climate hazards, identified hazard-prone vulnerable groups based on the vulnerability assessment framework, and conducted a preference ranking with households. The results became inputs for the organization of the architectural design competition on housing in Da Nang and the development of questionnaire instruments (household surveys) to collect primary data for the quantitative CBA.	The research team organized the design competition and administered the household surveys. Results of this step included the final housing design model selected for use in the quantitative CBA and damage estimates that informed the quantitative CBA.	The research team analyzed data and investigated the economic return on typhoon resilient shelters.

Endnotes

1. A storm with a wind speed of 118 kph (Category 12 on the Beaufort scale) is called a typhoon.

2. Other vulnerable sectors are agriculture, transportation and infrastructure, trade, and services.

2. RESEARCH METHODS

The research employed multiple disciplines and multiple stakeholders in combination with SLDs, the Resilient Housing Design Competition, surveys, climate analysis, and economic analysis.

2.1 Shared Learning Dialogue (SLD)

The SLD process brings together different stakeholders and therefore different types of knowledge, both scientific and local. It is intended to generate discussion and innovation based on new understanding of climate change, risk, and uncertainty. SLDs are founded on principles of meaningful public participation—bringing together stakeholders with different interests, perspectives, information, knowledge, and power—in a public arena of debate on a level playing field (Institute for Social and Environmental Transition, National Institute of Science and Technology Forecast and Strategy Studies, & Thailand Environment Institute, 2012). In this research, three types of SLDs were held in Da Nang with related stakeholders: (a) Local Architects and Builders (Private Sector) SLD, (b) Local Authorities and Experts (Government Sector) SLD, and (c) Local Communities (Households) SLD.

Private sector. The first type of SLD, consisting of two SLDs, was organized with local architects and builders to discuss and consult on issues related to the Resilient Housing Design Competition (e.g., content, method, procedures, and scope).

Government sector. The second type of SLD was organized with local authorities (at both city and ward levels) and experts. This included a first SLD with the city's Department of Construction to explore housing construction in the city (including construction planning, policies, codes, permissions, etc.). The second SLD was with the ward's authorities to gain understanding of the issues around housing, past floods and storms, and impacts on local communities in the past. The third SLD was held with experts from a consultancy company focused on housing design and construction to investigate the status of climate resilient housing in the city.

Households. The third SLD series involved local communities and was organized in three selected wards of the study area: Man Thai, Hoa Quy, and Hoa Hiep Bac. Objectives of these SLDs were to identify the options for increasing the climate resilience of the housing sector and to collect qualitative information about the costs and benefits of typhoon resilient housing.

2.2 The Resilient Housing Design Competition

The objective of the design competition was to seek the best solutions for housing in response to climate change and the impacts of urbanization. The targeted design competition locations were areas highly vulnerable to climate change in Da Nang. The target groups were the poor and low-income households living in these areas. Through this competition, the research team hoped to find appropriate housing models that would effectively build resilience to climate change and respond to urbanization in Da Nang. Priority was given to cost-effective designs for low-income and vulnerable groups. The competition was judged by shared learning groups and local experts.

2.3 The Surveys

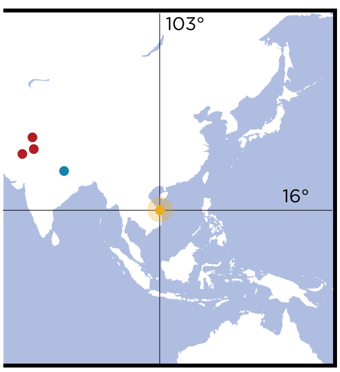
Figure 1 shows the study area locations of the surveyed households. In order to select study wards that were representative of the city in terms of vulnerability to typhoons, several SLDs with local authorities and experts were organized in Da Nang. Based on the SLDs' results, three wards were selected for household surveys to collect information about housing damage due to past typhoons: Man Thai (Son Tra district), Hoa Quy (Ngu Hanh Son district), and Hoa Hiep Bac (Lien Chieu district). Hoa Hiep Bac and Man Thai are representative of wards located in coastal areas, which are directly impacted by typhoon winds. Hoa Quy is located in a low-lying area of Da Nang city, which is often affected by typhoons and floods.

A household questionnaire was developed by researchers from Hue University in close consultation with experts at ISET-International. The purpose of the survey was to collect historical information on past damage associated with typhoon events. In the final survey, 98 questionnaires[1] were completed during face-to-face interviews conducted during May and June of 2012. The distribution of household samples followed the

FIGURE 1

MAP OF DA NANG CITY AND THE STUDY WARDS

This map is used for illustrative purposes only.



MAP KEY

- Urban Boundary
- Road
- Water
- Flood Survey Sites
- Design Demonstration Site
- Temperature and Humidity Sites
- Shared Learning Sites
- India Research Site
- Vietnam Research Site
- Pakistan Research Sites

sampling design,[2] and households that participated in the final survey were randomly selected in the study areas based on the list of households affected by the Xangsane (2006) and Ketsana (2009) typhoons. To increase the validity and accuracy of the data collected, supervisors randomly selected completed questionnaires and did re-interviews and cross-checks.[3] The questionnaires completed each day were carefully checked to make sure that information was recorded in the correct manner. Finally, these questionnaires were entered in data analysis software for data cleaning and analysis.

2.4 Climate Analysis

The main hazard of analysis for this research was typhoons; therefore, the climate analysis explores the increased frequency and intensity of future typhoon events to 2050. However, for the typhoon analysis there was inadequate data for projection, so a literature review was conducted instead. Research examined recent typhoon trends and possible changes in typhoon frequency and intensity in the future by conducting scenario analysis that assumes no climate change and climate change.

Without Climate Change Scenario

In the no climate change scenario, the climate remains the same as today; the frequency and intensity of severe typhoons (those that directly hit Da Nang with a Beaufort scale rating above 9) over the next 25 years is similar to the frequency and intensity of severe typhoons over the past 25 years (see Table 2). In other words, the 2006 Xangsane (Category 12) and 2009 Ketsana (Category 10) storms are each repeated once over the next 25 years. This is a conservative assumption; many storms have hit Da Nang in the past 25 years,[4] but these two storms were the largest in the last quarter century, causing significant damage to communities in Da Nang. With current construction standards, the housing stock damages thresholds are above the threshold storm strength of Category 9. Therefore, all historical storms above this threshold are considered. Also, the recurrence and distribution of typhoon strengths do not follow identifiable patterns like rain or flood depth curves.

With Climate Change Scenario

The second scenario assumes that in the future typhoon frequency stays the same but typhoon intensity increases.[5] Greater intensity may lead to greater damage, but this is not a linear relationship. In this scenario it is assumed that two typhoons like the 2006 Xangsane event will happen in the next 25 years. With this assumption, we recalculate the avoided damages, estimate benefit-cost ratios (BCRs), and compare them with the results of the "without climate change" scenario.

TABLE 2

AVERAGE DAMAGE COST PER HOUSE FOR HOMES DAMAGED BY THE XANGSANE AND KETSANA TYPHOONS

(Unit: VND 1,000[a])

Typhoon[b]	Total damage	Total damage adjusted to inflation in 2012	Total damage per standardized house in 2012
Xangsane in 2006	42,812.16	74,701.10	121,015.79
Ketsana in 2009	35,382.18	60,167.40	85,437.70

[a] USD 1 is equivalent to VND 20,800 (Vietcombank, 2012).

[b] The rationale for selecting these storms as the basis for this analysis is discussed in section 2.4 (Climate Analysis).

TABLE 3
BEAUFORT SCALE CATEGORY

Extended Beaufort scale category	Wind speed (kph)	Typhoon category
12	118 (kph)	Typhoon
13–14	119–156 (kph)	Strong typhoon
15–16	157–193 (kph)	Very strong typhoon
17	≥194 (kph)	Violent typhoon

2.5 Economic Analysis

A quantitative CBA is the main component of the economic analysis. Quantitative CBA is an established tool for determining the economic efficiency of development interventions (e.g., typhoon resilient housing). A quantitative CBA compares the benefits and costs of typhoon resilient housing and calculates the economic efficiency measured by the net present value (NPV), the internal rate of return (IRR), and the BCR.

Benefits. Benefits are the additional outcomes generated by the intervention project (i.e., resilient housing) compared with a situation without the project. The benefits of resilient housing are defined as *the avoided damage and loss* or *the accrued benefits following the adoption and implementation of resilient housing*. Avoided damage is the difference in damages and losses under two circumstances: with and without undertaking the typhoon resilient housing measures.

Costs. Costs are the additional costs of resilient housing. Results of the design competition (i.e., selected housing designs) were used to estimate the costs of resilient housing. Costs of resilient housing include (a) major investment costs for building a resilient house (construction costs) and (b) operation and maintenance expenses for the house incurred over time. This study focuses on the extra costs incurred by a typhoon resilient house as compared to a standard house.

The approach of this quantitative CBA is a combined backward-and-forward-looking approach that can be applied to assess current and future typhoon risks. Review of past typhoon impacts provided estimates for current risk, while projected climate and exposure changes were used to estimate risk for the next 25 years.

The present value of the benefits from resilient housing are highly sensitive to the timing of damaging typhoon events

Backward-looking analysis. Typhoon damage due to the 2006 Xangsane and 2009 Ketsana typhoons was estimated using the household surveys, which yielded total damage[6] information for housing (Table 2). As CBA must be performed under present conditions, damage costs from past typhoons in 2006 and 2009[7] were converted to 2012 levels using yearly inflation rate adjustments and reported in Vietnamese dong (VND). Floor space of housing in the study site has increased over time. Results of the household survey show that the floor space of a typical house in 2006 was about 50 m^2, but in 2012 it had increased to 81 m^2.[8] Thus damage per square meter was calculated and then adjusted to reflect a standard house in 2012,[9] as shown in Table 2. By utilizing this backward-looking approach, we were able to identify what damages an average household experienced in the 2006 and 2009 typhoons and use this information to build the forward-looking analysis.

Forward-looking analysis. The present value of the benefits from resilient housing are highly sensitive to the timing of damaging typhoon events; however, typhoon events are stochastic, or random. Moreover, typhoon damage is related to wind speed and direction, and it is difficult to correlate wind speed, damage, and return periods for typhoons. Therefore, the study utilized a *scenarios approach* to investigate the future economic impacts of typhoons in Da Nang city. Specifically, the research investigated two scenarios: (a) without climate change and (b) with climate change.

To test the economic soundness of the investment, each scenario was run with typhoon events occurring at different times over the lifetime of the house (the average lifetime of a house in Da Nang is 25 years). A "base case" approach assumes that there is equal probability that either of these typhoon events could occur over the lifetime of the house; thus, the total damage caused by both typhoons is evenly distributed over the lifetime of the house. However, whether a typhoon hits earlier or later in the lifetime of the house has a big impact on the returns from the risk reduction investment (Dobes, 2010). To show the ranges of potential returns, an early case scenario (events occur early in the lifetime of the house) and a late case scenario (events occur late in the lifetime of the house) were developed to show the range of BCRs that might be expected.

Whether a typhoon hits earlier or later in the lifetime of the house has a big impact on the returns from the risk reduction investment

Key assumptions for CBA. Review of the risk analysis has identified a number of key assumptions driving the CBA design and results. These are summarized in Table 4.

Sensitivity analysis. A sensitivity analysis was performed on a range of discount rates in recognition of the fact that these rates often vary between institution and by year. A full range of discount rates from 5%–15% was used for the sensitivity analysis.[10]

TABLE 4

KEY ASSUMPTIONS DRIVING THE CBA

Assumption	Value	Notes (sources)
Construction costs per house	68,937.11 (VND 1,000)	Additional cost of resilient housing; cost of resilient housing minus cost of nonresilient housing per house (calculation based on the results of housing design competition)
Lifetime of house	25 years	Using market rate based on market lending rate in 2012
Discount rate	10%	Market discount rate in 2012
Annual asset growth	2.46% per year	Annual increase in exposure of household assets (authors' calculation)
Operation and maintenance (O&M) costs	2% per 5 years	An increase in additional cost for housing resilience; occurs every 5 years
Economic depreciation	2,757.48 (VND 1,000)	Straight line economic depreciation method used; this refers to the allocation of the cost of housing assets to periods in which the assets are used (not the decrease in value of assets)

Endnotes

1. The household questionnaire is available upon request.

2. Based on the number of households affected by the 2006 and 2009 typhoons in three selected study wards, 120 households were selected for the final survey (see details of the sampling framework in Tuan, Phong, Hawley, Khan, & Moench, 2013).

3. It is noted that the respondents may have thought they could influence policy in favor of resilience by overstating the damage costs. To reduce this incentive, during the interview we cross-checked their reported damage data against secondary damage data provided by the local authorities.

4. For example, during the period from 1976 to 2011 (36 years), 59 storms and tropical low pressure systems affected Da Nang, or about 1.6 storms and tropical low pressure systems per year (Da Nang Hydro-Meteorological Station, 2012).

5. This assumption is similar to the results of climate projections for Vietnam published by the government, which predict that in the future there will likely be fewer but more intense typhoons in the region (Vietnam Institute of Meteorology, Hydrology, and Environment [IMHEN], 2013).

6. Total damage = direct damage (damage to housing and household assets damaged) + indirect damage (working days lost, evacuation costs, health and medical fees, cost of hiring local builders, cost of purchasing materials for housing repair or reconstruction, etc.). This study does 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. Typhoons lead to critical social disruptions, human casualties, and so forth, but due to the difficulty of quantifying these economic costs, the study does not include them in the overall analysis.

7. To reduce recall method bias (i.e., respondents might not remember housing damage that happened 5–8 years ago), we cross-checked their report of damage against the ward's housing damage reports provided by the local authorities.

8. The relationship between floor space and housing damage was observed from the household survey data by checking Spearman's Rho correlation. The result shows that it is significant at a (a 0.01 level).

9. The underlying assumption is that the larger the floor area, the greater the damage. Given the nature of the hazard, the major damage is to roof structure. The damage increases in direct proportion to the covered area or exposure. A large roof with the same strength of construction as a smaller roof should theoretically be more vulnerable, as the strength remains the same or reduced as the room size increases (because the distance between supporting walls increases) and the exposure increases (because total force due to wind pressure increases as it is applied over a larger area).

10. The discount rate of 5% recognizes that housing is a social welfare development program, with its effect mainly seen in the long term. The discount rate of 10% is the common base for a CBA study and is widely cited in the existing literature (Thang & Bennett, 2005; Truong, 2011; Tuan & Navrud, 2008). The discount rate of 15% is used to describe the current context of economic crisis.

3. RESULTS AND DISCUSSIONS

3.1 Results From the Climate Analysis

Recent Typhoon Trends

Tropical storms tend be larger and more intense in the Western North Pacific (WNP) basin than in any other ocean basin (Chavas & Emanuel, 2010). A number of different agencies, such as the Hong Kong Observatory and the Regional Specialized Meteorological Center in Tokyo, monitor the development, movement, and strength of typhoons in the WNP and keep historical records of past typhoons. There are differences in the records—called *best track data*—among the agencies. Records extend back only to the 1950s, and early records are not as reliable as those from more recent periods.

Depending on which data set is used, some researchers have detected a small decreasing trend in the overall number of tropical storms and typhoons between 1990 and 2008 for central to south Vietnam, and no trend in storms making landfall in north to central Vietnam (Chen & Lin, 2013; Yokoi & Takayabu, 2013).

However, this small decreasing trend could be part of natural multi-decadal variability. There is no observable trend in the number of very strong or violent typhoons from 1977 to 2007 (Tong et al., 2010). Frequency analysis of tropical storm and typhoon data provided by the Vietnam CCFSC shows no trend in the number or severity of tropical storms and typhoons impacting Da Nang or the central Vietnam coastline near Da Nang.

Possible Future Changes in Typhoon Intensity

Preliminary studies project the possible changes to typhoons impacting Vietnam:

- The overall number of typhoons forming in the East Sea and making landfall in Vietnam is likely to decrease according to multiple climate models (Tong et al., 2010; Yokoi, Takayabu, & Murakami, 2012).
- Climate models do not consistently project whether the number of very strong or violent typhoons will increase or decrease. Some multi-model studies show a potential increase in these types of typhoons, while others show a decrease (Tong et al., 2010).
- Projections from research by the Vietnam governmental authority suggest fewer but possibly more intense typhoons (Vietnam IMHEN, 2013).

3.2 Results From the Resilient Housing Design Competition

First prize in the Resilient Housing Design Competition was given to the design project that addressed local issues as they pertain to disaster resilience. The first prize winner presented three housing designs: tube, three-compartment, and twin double-story, as shown in Figure 2. These designs were developed from existing local housing forms. The models were highly praised for their functional and spatial appropriateness to local lifestyles and their high potential for replication in a wider region. In addition, according to the evaluation panel's comments, these designs were financially affordable for low-income families and offered safer and more comfortable living spaces than their current homes.

The winning designs addressed three outstanding issues related to the promotion of disaster resilient housing: site planning, building design, and construction technology (see Figure 3).

Site planning. Settlement patterns were taken into account, with an emphasis on the use of nonparallel or zigzagging roads and unequal distribution of houses to split wind flow and reduce wind pressure on buildings.

Building design. Simple building forms (rectangular or square) and pitched roofs were employed as key principles in designing individual houses for typhoon risk reduction.

Construction technology. Two fundamental elements of resilient housing were incorporated: (a) all building parts, from the top to the bottom, are securely connected by reinforced concrete beams and pillars; and (b) the structure has a solid room, known as a *safe failure room*, made with reinforced concrete that can be used as an on-site shelter during calamitous typhoons (i.e., over Category 12).

FIGURE 2

THREE HOUSING MODELS PROPOSED BY THE 1ST PRIZE WINNER

Left: Tube house; **Top Right:** Twin double-story house; **Bottom Right:** Three-compartment house
Source: Thang et al., 2013.

FIGURE 3

KEY ISSUES IN THE DEVELOPMENT OF DISASTER RESILIENT HOUSING

Left: Site planning includes nonparallel or zigzagging roads and buildings; **Top Right:** Construction technology defines that all building parts must be securely connected; **Bottom Right:** Safe failure is addressed by including a solid room in the house (shown in red). Building design includes simple building forms (rectangular or square) and high-sloping or pitched roofs.

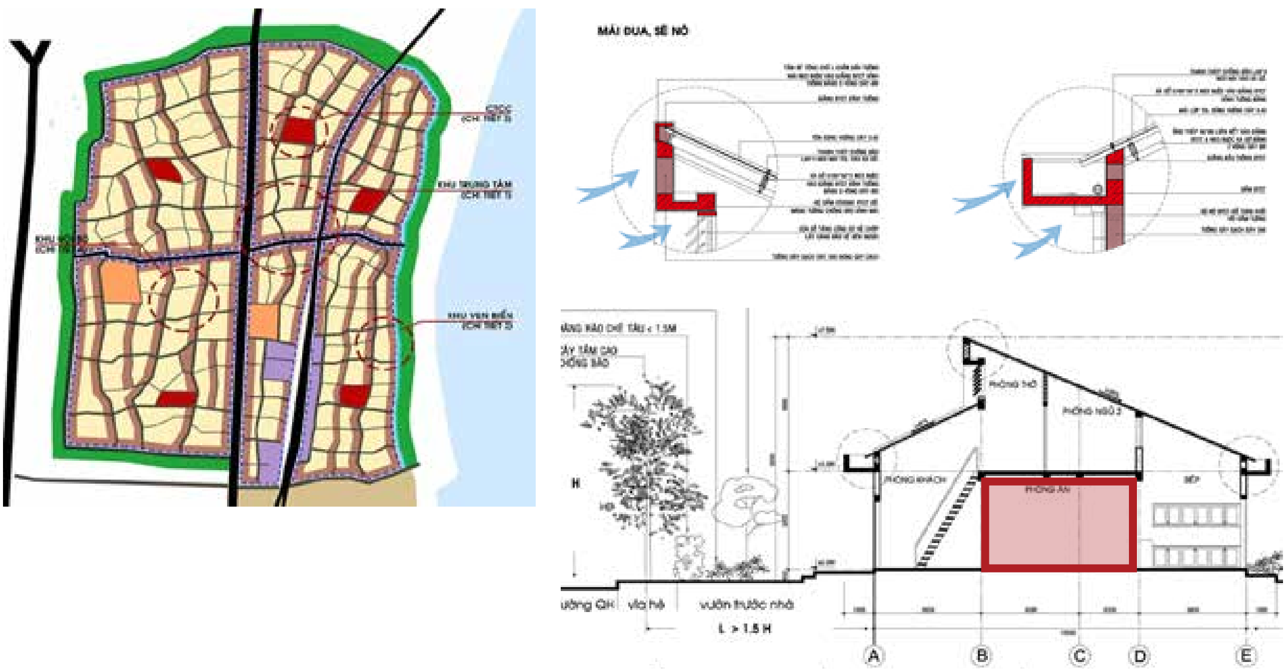
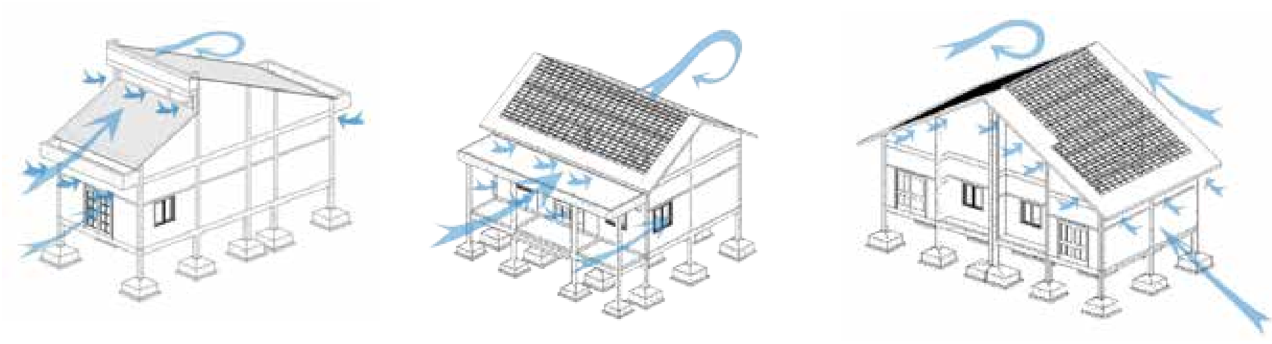


FIGURE 4

TYPHOON RESILIENT STRUCTURE DESIGNS BY THE 1ST PRIZE WINNER

Left: Tube house; **Middle:** Three-compartment house; **Right:** Twin double-story house
Source: Thang et al., 2013.



Impact on Future Housing Developments

Results of the design competition also addressed design-related issues that may impact future developments in climate resilient housing. These issues ranged from physical (e.g., unsafe condition of existing local houses) to social (e.g., economic constraints on low-income families) to administrative (e.g., lack of safety-related building codes or construction standards in hazard-prone areas).

Physical issues. The winning designs were completely based on lessons learned from the local context and experiences. Three housing forms (tube, three-compartment, and twin double-story) dominate local Da Nang construction styles. These forms are already appropriate for people's lifestyles and community settings. In terms of typhoon resilience, these building shapes have already proven effective at reducing wind pressure. The winning designs simply added two core building principles to existing housing forms to increase structural stability: the incorporation of posts and beams into the structure and strong connections for roof reinforcement (see Figure 4).

Social issues. The design competition identified four major challenges to the promotion of climate resilient housing in the context of Central Vietnam. The first challenge is the economic constraints generated by unstable livelihoods, a high rate of unemployment, and temporary low-paying jobs. In Central Vietnam, particularly among poor and low-income groups, economic difficulties make DRR a secondary priority after basic needs such as food, health care, and school fees for children. The second challenge is limited awareness about climate change and the importance of climate risk reduction for long-term development. This lack of awareness has led local people to underestimate the actual danger of climate hazards, causing them to prefer immediate or short-term responses. Local people often think of disaster preparedness and risk reduction when they hear an announcement of an approaching hazard on mass media; they then rush to respond with quick and simple measures, such as putting sandbags on roofs, moving valuable items to a safe place, or evacuating if it is a big event. The third challenge is the limited skills of local builders, usually masons, in building safer and more resilient shelters. Da Nang has experienced strong typhoons, as when typhoon Xangsane seriously impacted the city in 2006. The skills and techniques of local builders were inadequate to address safety issues and are likely to reproduce risk to future hazards in new construction. Finally, lack of communication and consultation with in-field experts and professionals (i.e., local architects and engineers) is the fourth major challenge faced by poor and low-income groups when building resilient shelters. Currently, poor and low-income groups pursue construction on their own and lack technical guidelines for building disaster resilient structures. All of these challenges are considered key obstacles to a wider application of resilient housing designs.

Administrative issues. There seems to be a lack of local governance related to safe construction. To date, building codes and construction regulations related to DRR have not been applied in the study sites. Building permits are not required for most local housing construction, particularly for single-story houses. People freely choose their housing forms and construct their houses according to their needs and financial capacity. Many unsafe conditions can be found in the houses of poor and low-income groups, who lack technical support and were not informed of the regulatory requirements for safe construction. This limited oversight strongly influences housing vulnerability and may undermine future efforts to develop a climate resilient housing system.

3.3 Results From the Qualitative Ranking

To determine which options to investigate through CBA, the research team looked at the results from the SLD series with local communities, which identified three key options that local households consider to be potential typhoon resilience strategies. These options included (a) building a new house, (b) retrofitting/repairing a house, and (c) building public shelters.

Characteristics of Typhoon Resilient Housing Options

Option 1—building a new house. Typical characteristics of a house that is both resistant to severe typhoons (Category 12 on the Beaufort scale) and economically feasible for medium- and low-income households[1] include a floor area of 50 m^2 (a four-to-six person house), reinforced concrete columns and a bond beam, a mezzanine, and medium-quality materials. Under current housing conditions in the study areas, the total cost to build a new house is estimated at about VND 125 million (average cost VND 2.5 million per square meter). The lifetime for use is about 15–20 years, and in some cases it may be much shorter depending on the economic status of the household.

Option 2—retrofitting a house. Repairing or retrofitting a house using typhoon resilient techniques is a viable option for local communities to respond to typhoon risks, particularly poor households with budget constraints. Typically, a house is considered retrofitted if it has been reinforced with six concrete columns and a metal roof that is secured to the walls. For an area of 40 m^2 with six reinforced concrete columns and a bond beam, this housing option costs about 50% of the total cost of rebuilding a house (Option 1). The lifetime for use is only about 7–10 years, as other parts of the house (nonretrofitted) are still weak. Data from 12 households living in the three study wards show that the average size of a repaired house is 38 m^2 (range 20–75 m^2), with an estimated cost per square meter of VND 1,107,143 (Da Nang Women's Union, 2012). The total cost of repairing a house varies substantially among households and depends on the quality of construction materials, size of the house, and household budget. Retrofitting is rapidly becoming a dated option.

Option 3—building public shelters. This is a popular solution to enhance local resilience to floods in rural areas of Central Vietnam and has been adopted as a model for typhoon resilience. The first public shelter in Da Nang was built in Hoa Quy ward in 2006 at a total cost of about VND 600 million. The shelter is a concrete two-story house with an area of 300 m^2. The public space not only serves as a shelter for local people when floods and typhoons occur, but also serves as an activity and meeting place. There is a kitchen, toilet, and power generator, and enough beds and supplies to provide shelter for around 300 people for about a week. This type of shelter is an extremely practical option for people who live in low-lying regions, as there are few public buildings in these areas. However, during the past few years of Da Nang's relocation program, many apartment buildings have been built for the relocation of households living in low-lying areas. Due to rapid economic growth, other safe buildings (such as schools, health care centers, public buildings, and private houses[2] with permanent structures) have also been built in these areas. As a result, many public shelters in Da Nang are abandoned, especially during nonflood seasons (*D.C.,* 2010). Therefore, the research team has chosen not to discuss the investigation into public shelters any further.

Identifying the Costs and Benefits Associated With Each Option

During the SLDs with local communities, several types of benefits associated with typhoon resilient housing were identified. Housing construction characteristics were categorized by sustainability, socioeconomic benefits, utility/functionality, and society/community. Types of costs (dis-benefits) associated with typhoon resilient housing options were categorized by construction expenses and risks, as displayed in Table 5.

TABLE 5

IDENTIFYING THE BENEFITS AND COSTS FOR OPTIONS IN THE SELECTED WARDS

Source: Tuan, Phong, & Hawley, 2013.

Option	Benefit				Cost	
	Sustainability	**Socio-economic**	**Utility/ functionality**	**Society/ community**	**Construction expenses**	**Risks**
Rebuild house	Longer life span and longer use time compared to retrofitting option (about 30 years and 15–20 years, respectively) Stronger resistance to typhoon wind (can be shelter to typhoon of level 12 magnitude)	Mitigate damages and loss of household assets and lives Safer shelter, stability in life, feel secure about the house, more chance to focus on livelihoods Owners are proud of new house Easier access to credit and loans	More utility than old and retrofitted houses Meets the demand for shelter of households Meets family's demands, more convenience for use	Neighbors are able to shelter in rebuilt houses when typhoons happen Communities do not have to support household individuals when typhoons hit	More expensive than retrofitting (about VND 2–4 million/m^2) Households that lack money may get a loan with a high interest rate	Because owners have to take a loan, they may delay or default on repayment, which has impact on life, health, and education of children
Repair house	Life span is about 15–20 years and use time is about 7–10 years Can be resistant to typhoon with level 9–10 wind magnitude	Household feels somewhat better about house security Some other benefits are similar to the "new house" option (such as safe shelter, reduced damage), but at a lower degree	Lower level of utility compared to rebuilding a house Little chance to improve the space and appearance of the house Partly meets household demands	Neighbors are able to shelter in repaired house when typhoons hit	Cheaper than the rebuilding option (about VND 1–2 million/ m^2)	Same as above

Overall Evaluation of Options

During the SLDs with local communities, the participants identified which option they would choose. Most participants in the SLDs selected "building a new house." The SLD facilitators explained that building a new house is more expensive than retrofitting a house. However, individual households still consider this to be the most effective and sustainable option. The SLD participants also revealed that about 40%–50% of the households in the study wards would be willing to take a loan to build a new house if loans were available. Overall, households preferred to build a new house over repairing a house; therefore, this option was investigated further quantitatively.

3.4 Results From the Quantitative CBA

This section presents the economic returns of typhoon resilient housing (measured by NPV, IRR, and BCR) for two scenarios.

Scenario 1: Without Climate Change

In Scenario 1, we assume that the frequency and intensity of typhoons in the future is the same as in the past, that is, that two typhoons occur, one with the strength of Ketsana and one with the strength of Xangsane. The NPV, IRR, and BCR are calculated with typhoon events occurring at different points in time over the lifetime of the house.

The SLD participants also revealed that about 40%–50% of the households in the study wards would be willing to take a loan to build a new house if loans were available.

Photo: Phong Tran, October 2013

TABLE 6

CALCULATION OF BCRs IN THE "WITH CLIMATE CHANGE" AND "WITHOUT CLIMATE CHANGE" SCENARIO

[a] Parentheses indicate a negative value.

	Without Climate Change			With Climate Change		
Measurement	**Base case**	**Early case**	**Late case**	**Base case**	**Best case**	**Late case**
NPV (VND 1,000)	66,069.35	152,941.30	(35,218.32)[a]	96,452.11	200,532.32	(28,144.22)[a]
IRR (%)	11	121	-	16	132	-
BCR	1.93	3.15	0.50	2.36	3.82	0.60

The first option (i.e., the base case) assumes that there is equal probability that either of the two historic typhoon events could occur over the lifetime of the house (i.e., the probability of the event happening in any year is equal). Results of the base case (reported in Table 5) show NPV>0, BCR>1, and IRR>10% (i.e., the market discount rate). This implies that the economic return on investment in typhoon resilient housing is desirable. It should be noted that this is a conservative result/estimate, as the analysis did not include many smaller storms that have occurred in the past 25 years.

Results show that if the typhoons happen very early in the project lifetime—particularly, if the 2006 typhoon (Category 12) happens in year 1 and 2009 typhoon (Category 10) happens in year 3[3]—the returns are optimal (the best case). Conversely, if the typhoons happen very late in the project lifetime (the 2006 typhoon happens in year 25 and the 2009 typhoon happens in year 23), the returns are the worst (the worst case). This implies that any loss happening later in the lifetime of the investment minimizes the benefit of resilient construction.

In the base case, the results show that IRR equals 11% (i.e., higher than the market discount rate), which implies that it is preferable to invest in resilient housing rather than the bank. The best case occurs when the typhoons happen very early in the project lifetime. This was somewhat reflected in the recent landfall of typhoon Nari,[4] which hit Da Nang in mid-October 2013. However, this does not necessarily mean that the probability of this happening is greater.

It is of interest to investigate the year when a typhoon event would result in an NPV break-even point (break-even case: from a positive NPV to a negative one). The analysis results show that the break-even case occurs if the 2006 event happens in year 16 and 2009 event happens in year 18 (see Figure 5). This means that if the 2006 event occurs after year 17 and the 2009 event occurs after year 19 of the project lifetime, NPVs become negative.

For the sensitivity analysis, varying interest rates with a full range from i equals 5% to i equals 15% were used; IRR results ranged from 16% to 6%, respectively, as shown in Figure 6.

Scenario 2: With Climate Change

As stated earlier, the "With Climate Change" scenario shows an increase in the amount of damage that occurs over the lifetime of the house. In this scenario, we assume that the 2006 typhoon occurs twice in the next 25 years.[5] The returns on investment in typhoon resilient housing are reported in Table 6 and the IRRs for the sensitivity analysis are presented in Figure 7.

The results of Scenario 2 show that the base case IRR is 16% (compared to 11% in Scenario 1), the range of IRRs for the sensitivity analysis is 11%–21% (compared to 6%–16% in Scenario 1), and the break-even case takes place in years 19 and 21 of the housing lifetime. In other words, the returns of Scenario 2 are higher than the returns of Scenario 1. This implies that taking into account the impact of climate change would result in higher returns on investment.

FIGURE 5

THE BREAK-EVEN CASE

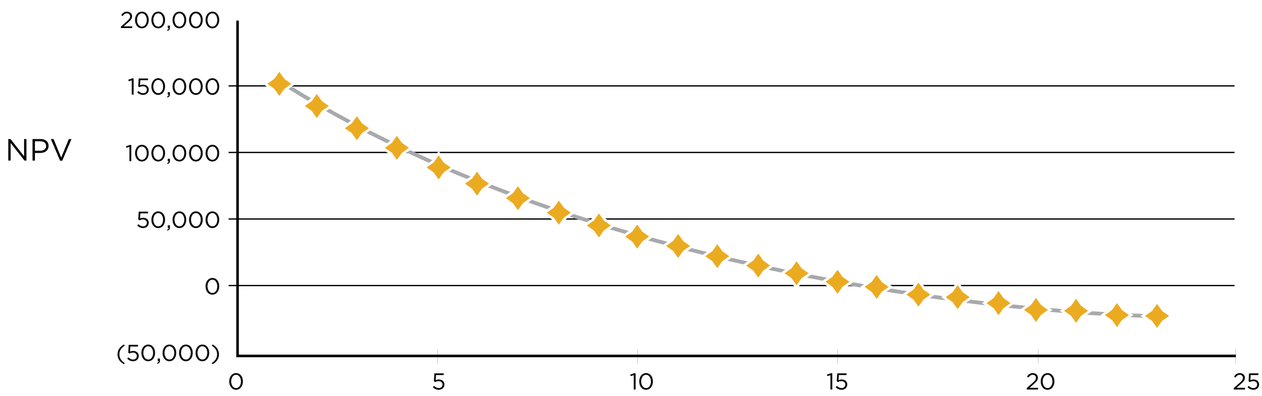


FIGURE 6

IRRs WITH DIFFERENT INTEREST RATES (SCENARIO 1)

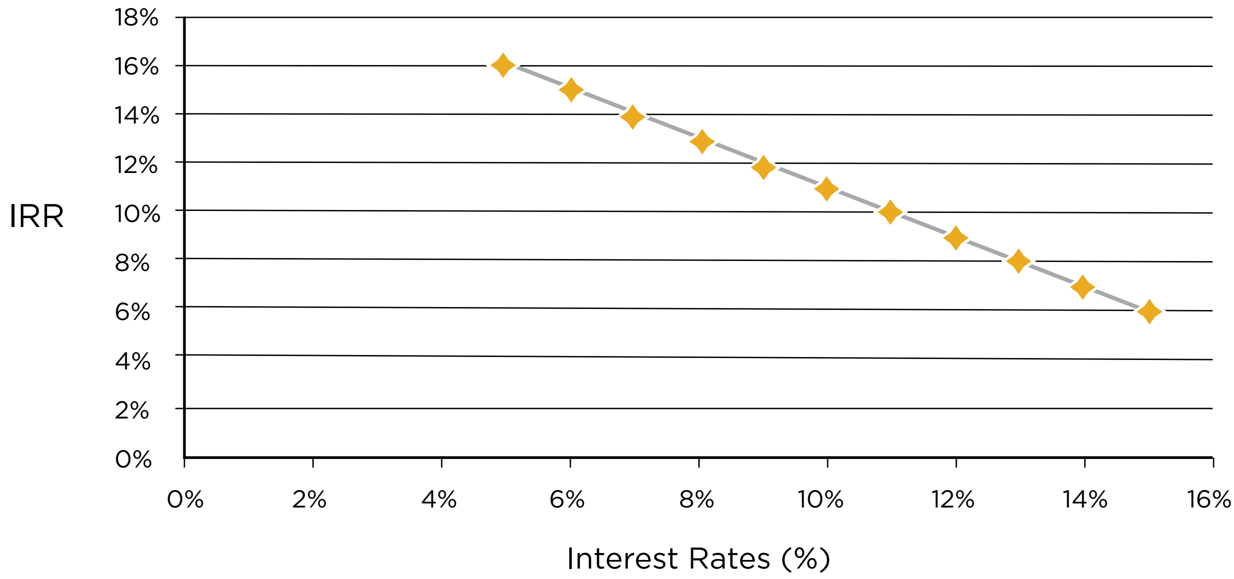
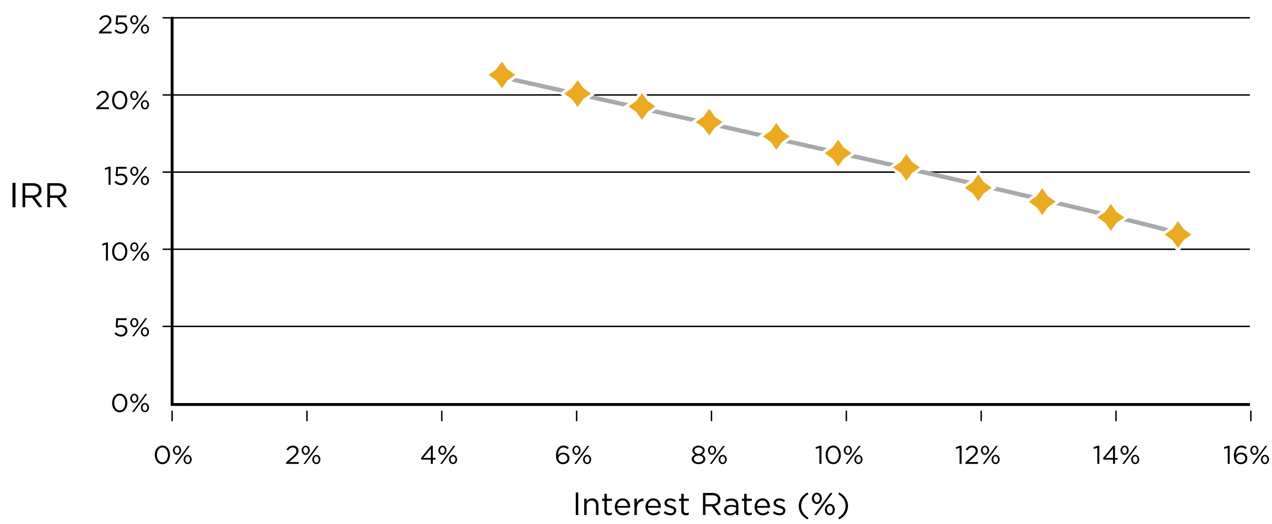


FIGURE 7

IRRs WITH DIFFERENT INTEREST RATES (SCENARIO 2)



Endnotes

1. The focus of this study is to investigate housing options for medium- and low-income households in the study areas, because higher income households usually already live in permanent houses. If high-income households plan to build a new house, it will likely be much larger and more expensive.

2. Private houses with permanent structures can be used for sheltering neighbors if a disaster occurs.

3. We assume that housing reconstruction takes 1 year.

4. Typhoon Nari (typhoon no. 11) hit Da Nang city at midnight on October 14, 2013, with level 12 winds and level 13 gusts, equivalent to 130 kph.

5. Again, this is a conservative assumption.

4. LIMITATIONS AND POLICY IMPLICATIONS

4.1 Scope and Limitations

Some limitations still remain in this research, as discussed in this section.

Exclusion of small storms from the analysis. Many storms have hit Da Nang in the past 25 years, but only two typhoons (Xangsane in 2006 and Ketsana in 2009) were used in the analysis. The reason is that these two storms were the largest in the past quarter century, causing significant damage to housing in the city. Other smaller, more frequent storms were not considered because these smaller events often do not harm housing stocks significantly.

Exclusion of intangible costs. For the quantitative CBA, in estimating the damage cost per household (which is considered as benefits of the resilient house), the study did not include intangible costs, such as cost of social disruptions within a group or community. Destruction of many houses in a community is likely to lead to critical social disruptions, where social relations among community members and local cultural values are threatened or demolished. Another form of intangible cost are the human casualties caused by typhoons. This creates a terrible loss for families, but is very difficult to convert into economic costs. As this study is intended to deal with the economic aspects of typhoon resilient housing, the damages that can be converted into economic costs have been included, but psychological problems—such as trauma, peace of mind, and safety concerns—and environmental benefits were not taken into account.

Exclusion of multiple hazards. This study has the limitations of single-hazard analyses (i.e., typhoons and typhoon-associated floods). If it took into account the issue of multiple hazards, such as floods, droughts, and earthquakes, the costs might increase significantly.

Issue of intensity thresholds. The housing design competition limited the capacity of typhoon resilient housing to a typhoon intensity of level 12 on the Beaufort scale (about 120 kph). This means that this type of housing may not be resilient if there are typhoons of stronger intensity[1] in the future.

Case-specific cost of typhoon resilient housing. The cost of typhoon resilient housing was estimated based on the winning project/model in the design competition and is therefore case specific. Even though this housing model was considered the best representative of typhoon resilient housing for Da Nang city, the cost associated with this housing model is very much dependent on the quality of materials, design features, floor area, and so forth. In reality, local people may build a larger or smaller house, use a different quality of materials, employ different design features, and so forth, and hence the associated cost of resilient housing could vary widely.

Uncertain return on investment. Due to variations in housing design features, degree of typhoon intensity, the discount rate used, and future climate uncertainty, the return on investment in typhoon resilient housing carries high uncertainty, which may limit the accuracy of research results.

4.2 Policy Implications

This study investigated typhoon resilient housing measures undertaken by individual households. We now unlock the policy implications for households as well as public sector interventions.

Implications for Individual Households

The returns on typhoon resilient housing investment are positive and high in some scenarios, implying that local households should prioritize this investment. However, because individual households have budget constraints and options when investing in their homes, the aesthetics, structure, or size of their homes may not factor into their decision making. In addition, opportunity costs come into play here and additional cash that could be invested in a typhoon resilient house may be invested elsewhere (e.g., in their children's education).

In addition, as pointed out by Kunreuther, Meyer, and Michel-Kerjan (2010), people with low incomes consider the near term rather than the future term, given that they often face extremely pressing and immediate problems. These limitations affect a household's decision to invest in typhoon resilient housing. These limitations also have implications for public policy, as discussed in the next section.

Deputy Prime Minister Nguyen Xuan Phuc, on 9th November 2013, inspected preparations for the super typhoon Haiyan, which was expected to make landfall in central provinces on November 10.

Photo: Red Bridge, 2013

Implications for Public Policy

Encouraging Individual Investment

The quantitative CBA results show that typhoon resilient housing exhibits high BCRs in some scenarios. To encourage individual investment in typhoon resilient housing, the government should consider offering assistance to households that agree to undertake appropriate climate resilient housing measures. This encouragement could 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, including Da Nang (Decree 716, 2012). With this pilot program, 40,000 households will be directly supported with cash (about VND 10–12 million) and a loan with a low interest rate (VND 15 million). However, this program did not consider the issue of typhoon resilience. It is essential to include the issue of typhoon resilience in this program in order to improve housing resilience for the poor.

Promoting Micro-Insurance Policies

Micro-insurance mechanisms have been viewed as an efficient and reliable risk management tool for encouraging households in developing countries to adopt DRR measures (Linnerooth-Bayer, Bals, & Mechler, 2010; World Bank, 2012). Index-based disaster insurance policies for flood and drought have been widely applied in low-income countries (World Bank, 2012), but typhoon insurance is still new.

Typhoon insurance policies were pioneered in the Philippines in 2009 to protect Filipino farmers against typhoon-related losses (International Finance Corporation, 2013). This would seem to have relevance for Central Vietnam, where several typhoons hit each year. Vietnam has created a subsidized public-private partnership for agricultural crop, livestock, poultry, and aquaculture insurance, which the government promoted with premium subsidies between 2011 and 2013 (World Bank, 2012). Therefore, for future DRR, typhoon insurance could be an appropriate application.

Results from current climate projections show that fewer but more intense typhoons may affect Vietnam in the future.

Adopting Multi-Hazard Resilient Construction

Results from current climate projections (Vietnam IMHEN, 2013) show that fewer but more intense typhoons may affect Vietnam in the future. Typhoons like Xangsane will still occur and may be even stronger,[2] causing significant damage if people are not prepared. Furthermore, flood models show that climate change will increase the severity of flooding in Da Nang in the future (Opitz-Stapleton & Hawley, 2013). Including flood hazard in our analysis would increase the cost of building resilient housing due to the additional cost for flood resilience; however, the benefit would be greater because an increase in flood intensity would lead to an increase in avoided damage (i.e., the benefit of resilient housing), and this would result in a positive return on investment. It is therefore important that housing construction adopt multi-hazard resilience measures.

Improving Awareness of At-Risk Communities and Stimulating the Local Economy

Social issues uncovered during the design competition support the idea that climate risk reduction efforts need to go beyond the physical aspects and include social enhancements such as raising local awareness and sustaining the local economy. For low-income groups, disaster preparedness is not as important as meeting the basic needs of living. For medium- and high-income groups, fashionable construction focused on decorative details is preferred over safe construction (Tuan & Phong, 2013). Adequate economic resources are needed to allow people to build resilient housing and plan for long-term development, and homeowners need better information about resilient housing options and their benefits.

Bridging the Gap Between At-Risk Groups and In-Field Professionals

Vulnerable communities in the study, such as the poor and low-income groups, experience economic constraints that hinder accessibility to professional services for better housing design and construction. Recent literature is increasingly concerned with the role of construction professionals in DRR, as professional expertise and skills are needed to assist at-risk communities in coping with future disasters (Tuan & Phong, 2013). Mutual and interactive learning and sharing processes among at-risk people and communities and in-field professionals are essential to achieve better communication.

Applying Safety-Related Codes and Criteria to Local Construction

Results from the design competition suggest that building codes and zoning/planning criteria for climate risk reduction are still lacking in hazard-prone areas. Current governance mechanisms for civil construction tend to focus on urban districts, with limited consideration for peri-urban and rural areas—places that are, in fact, more vulnerable to climate risks. Improving local construction practices through the application of safety-related regulations (in the form of building permits) would help to create an enabling environment for resilience and enforce a resilient housing system in Vietnam into the future.

Endnotes

1. This would have been the case if super-typhoon Haiyan, which made landfall in the Philippines as a Category 15 storm, had made landfall in Da Nang as a Category 16–17.

2. For example, super-typhoon Haiyan (a Beaufort Category 17 storm) was forecasted to approach Central Vietnam in November 2013.

5. CONCLUSIONS

Da Nang, located in Central Vietnam, is experiencing rapid development in locations that are highly vulnerable to flooding and the impact of typhoons. In 2006, typhoon Xangsane made landfall in Da Nang, causing devastating damage and losses to local communities, and destroying thousands of houses. Projections on climate change by government research authorities suggest that typhoon intensity is likely to increase, while typhoon frequency may increase as well in the Da Nang area (Vietnam IMHEN, 2013). The city also frequently experiences floods, and it is projected that climate change will intensify flood risk in Da Nang, as the city's growth and settlement tends to take place in low-lying areas.

5.1 Innovative Housing Designs Are Affordable

Housing construction in Da Nang has experienced great change as a result of economic improvement in recent years. For example, more durable but costly materials are being used in housing repair and construction instead of traditional materials. However, due to lack of guidance from professionals and authorities, the housing sector is highly vulnerable to flooding and typhoons. Results of the housing design competition proposed simple yet key alternatives—site planning, building design, and construction technology—to increase the typhoon resilience of housing, at the level of both individual households and local neighborhoods. The winning housing model responded and adapted to local contexts in that it was financially affordable for low-income households and could be replicated in a wider region. In addition, the winning model addressed design-related issues useful for future developments in climate resilient housing.

5.2 Typhoon Resilient Housing Can Be Economically Viable

Results of the quantitative CBA show that the returns on investment in typhoon resilient housing are high in some scenarios, meaning that investment in typhoon housing can be economically viable. The results show that the return is very much dependent on the year in which a typhoon event takes place. If an event happens early in the housing lifetime, results exhibit positive returns on the investment. The break-even case takes place if the 2006 typhoon happens in year 16 and the 2009 typhoon happens in year 18 of the housing lifetime. The results also show that if the impacts of climate change are taken into account, the return on the investment is higher.

5.3 New Public Policies Are Needed

The findings of this research have generated several policy implications at the individual and governance level. However, because individual households with low incomes have limited financial resources, they do not have enough money to invest in typhoon resilient housing. This limitation could be addressed by public policies, such as:

- providing subsidized loans,
- promoting micro-insurance policies,
- adopting multi-hazard resilient construction,
- improving awareness of at-risk households and communities and stimulating local economies,
- bridging the gap between low-income groups and in-field professionals, and
- applying safety-related codes and criteria to local construction to build safer and more resilient communities, particularly in low-income and disaster-prone areas.

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- Projecting the likely rise of future heat impacts under climate change for selected urban locations in South and Southeast Asia.

POLICY BRIEFS

- Gorakhpur: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Typhoon Intensity and Climate Change

TECHNICAL REPORT

- Gorakhpur: Extreme Rainfall, Climate Change, and Flooding
- Da Nang: Extreme Rainfall and Climate Change

Sheltering From a Gathering Storm aims to improve understanding of the costs and benefits of climate resilient shelter designs and contribute to the transformative changes necessary to make communities more resilient to future disasters.

This case study, one of three in the project, focuses on key issues related to housing in Da Nang, Vietnam, and provides insights into the economic and nonfinancial returns of adaptive, resilient shelter designs that take into consideration hazards such as typhoons, flooding, and temperature increases.

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