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Towards sustainable housing for Vietnam

(*Intended category: **Beyond Today's Infrastructure***)

Abstract

Economic development in Vietnam has led to the spontaneous development of new housing in many parts of Vietnam without consideration of environmental protection, cultural suitability, or resource reduction. The transition of Vietnamese housing into a sustainable industry is both an opportunity and challenge. Vietnam has to satisfy a growing demand for housing while confronting the issues of climate change, extreme weather events, nature conservation and cultural heritage. To that end, model green building guidelines are being developed to facilitate Vietnam's adoption of sustainable development principles and practices. This paper presents the results of a survey and interviews carried out in Vietnam to ensure that model green guidelines align with the cultural and consumer preferences of the Vietnamese people.

Keywords: *sustainability, sustainable housing, environment protection, tropical climate, green building guidelines.*

1. Introduction

Economic development in Vietnam has recently influenced housing design in both quantity and quality. According to Ho Chi Minh City Department of Construction (2010), the *Program for Urban Development* between 2011 and 2025 will provide 100-120 million square metres of new residential floor area in Ho Chi Minh City alone (7-8 million square metres of floor area each year). Compared with the 1999 national census and housing survey, preliminary data from this 2009 survey reflected a higher rate of housing developed with more construction quality (Steering Committee, 2009, p.8). The average net dwelling area per capita increased from 9.7 m^2 in 1999 to 13.2 m^2 in 2009 (Nguyen, 2009). However, the quality of existing housing for the survey needs to be reviewed because, according to the data, they were described as a structure that meets three basic criteria: (1) minimum gross housing floor area of 4 m^2, (2) minimum housing wall height of 2 m^2, and (3) being an independent and private structure (Steering Committee, 2009, p.7). In fact, the house is not just a structure with a floor area of more than 4 m^2, but a safe dwelling that provides health and well-being for occupants, adapts to regional climate and culture, and mitigates natural forces.

Despite the large quantity of houses constructed, the high demand for housing has not been met due to population growth and rapid urbanisation in Vietnam (Table 1). According to the 2009 national census, 5 in 10,000 families were homeless or their houses did not meet the above minimal criteria (Steering Committee, 2009, p.7). Moreover, limited and delayed innovations in construction methods have effected the speed of construction and the quality of buildings (Nguyen, 2005). As a result, increasing the number of houses has been deemed more important than improving housing quality in terms of indoor air quality, energy consumption, health and safety, and so on. Moreover, inhabitants need open spaces which provide for outdoor activities, environmental amenities, comfort and sense of community. In the two biggest cities of Vietnam, Hanoi and Ho Chi Minh City, many environmental issues have emerged, including serious traffic jams, urban flooding and air pollution, due to a delay of improvements of infrastructure, together with the urban population increase (Nguyen, 2010).

Table 1. Population, area, and density of Vietnam and its major cities in 2008. (Source: General Statistics Office, 2008).

		Population (person)	Area (sq.km)	Density (person /sq.km)
Major cities	Hanoi Capital	6,116,200	3348.5	1827
	Ho Chi Minh City	6,611,600	2095.6	3155
	Danang	818,300	1283.4	638
	Can Tho	1,171,100	1401.6	836
Whole country		**86,210,800**	**331150.4**	**260**

Figure 1. Map of Vietnam.

The use of high embodied-energy building materials and the lack of consideration of tropical passive design and green building codes, standards, or guidelines are major causes of the worsening environmental conditions. Today, cement, ceramics, tiles, steel, and glass, which consume a great amount of energy to produce, are preferred for construction in Vietnam. In fact, Vietnam is considered one of the top ten countries for cement manufacture in the world (Saigon Times Staffs, 2009). In 2008, Vietnam consumed 40.1 million tons of cement and the figure has increased over the following years. Some national building codes have been issued recently, in response to the need to control the quality of buildings, such as the Building Code of Disable Access in 2002, the Building Code of Energy Efficiency in 2005, and the Building Code of Dwellings and Public Buildings - Occupational Health and Safety in 2008. However, they are only compulsory for large scale buildings such as office high-rises or multi-story apartments. For low-rise housing, the designs have to comply with regional regulations, such as Decision 135/2007/QĐ-UBND of Ho Chi Minh City and Decision 19/2006/QĐ-UBND of Danang City, and the National Building Code of General Planning and Design, which lacked information about how to achieve a sustainable built environment.

Additionally, climate change brings threats to the built environment in Vietnam. Due to its topography, two major deltas in the North and the South are predicted to be inundated under the impact of sea level rise. Hanoi and Ho Chi Minh City are located in these deltas, and will be burdened with a population migration from surrounding flooding areas (Eckert and Waibel, 2009). Moreover, the increased temperature in the densely built inner cities, known as the urban heat island effect, is contributing to higher consumption of energy for cooling and ventilating buildings as well as affecting inhabitants' health and comfort (Eckert and Waibel, 2009). It is evident that in the 2010 hottest months (April to July), electricity was not sufficient for various cities in Vietnam, including Hanoi and Ho Chi Minh City, and inhabitants had to go without electric power. During the same period, Ho Chi Minh City consumed a recorded amount of energy, 49.38 million KWh per day, and had to face scheduled electric cut-down while the urban temperature reached to 38°C (Thai Phuong, 2010).

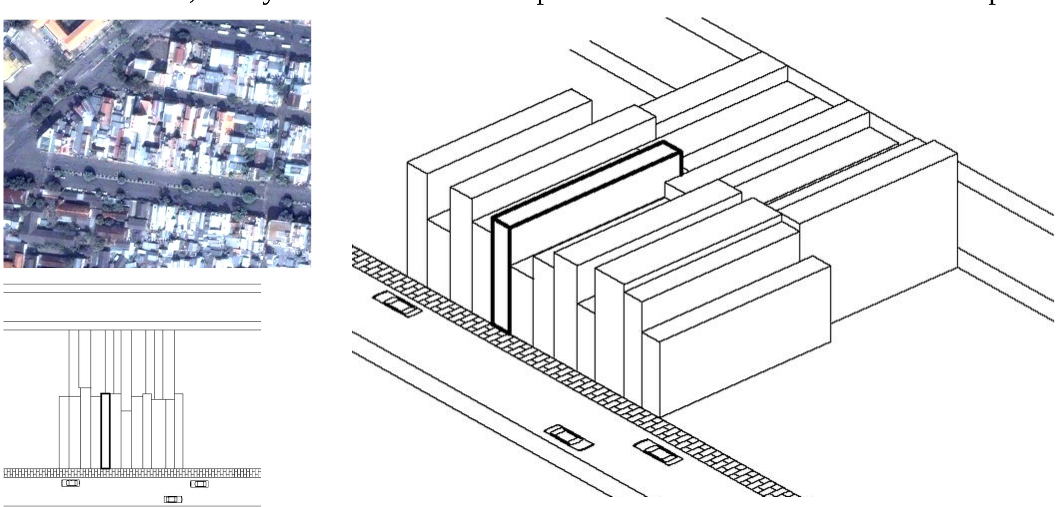
A transition to sustainability has thus become urgent for future housing in Vietnam. Guidelines are intended to provide principles for a built environment yet that can satisfy housing demand. Model green guidelines based on the vernacular Vietnamese architecture were developed to identify heritage values compatible with climate responsive housing design (Ly et al., 2010), this research focuses on the current housing context by using a quantitative methodology. Results of a survey with 350 householders' responses from Hanoi, Danang, Ho Chi Minh City and Can Tho and 14 interviews with architects, builders, authorities, and researchers in Vietnam in 2008-2009 are a basis for refining these sustainable housing criteria, with an aim to improve the quality of new and existing housing while respecting cultural aspects. Basic principles are studied, emphasising the selection of appropriate housing types and forms, the reduction of energy use by applying passive designs in the tropical Vietnamese climate, the promotion of solar energy, the provision of health and comfort for home occupants and ecosystems, the minimisation of resources, and the avoidance of household waste.

2. Housing types in Vietnam and their features

There are various types of housing developed in urban and rural areas of Vietnam. Row houses, detached houses, semi-detached houses, high-rise and low-rise apartments constitute the urban structure while traditional houses are built in rural regions. The urban houses are commercially constructed with 'modern' materials like concrete, steel, and glass. In contrast, the rural houses are built by their owners with locally available materials and climate responsive considerations. Typical housing archetypes that are used in Vietnam are described below:

2.1. Urban row house/ street house: The row house is a multi-storied structure usually located in a rectangular plot which has a width much shorter than its length (Ministry of Construction, 2005). The row house connects to a street or alley on its one narrow side, with the dedication of a part or whole of the ground floor areas for retail shops or an office. Therefore, it is also called street house or shop house. Many row houses sit together to form a continuous block of houses and share the same regional common infrastructure (Figure 2).

In some places, the row house has one floor level or many floor levels (up to six or seven) according to the width of the street it faces. These tall yet thin row houses can cause many issues of health, safety and comfort for occupants as well as the environmental impacts.



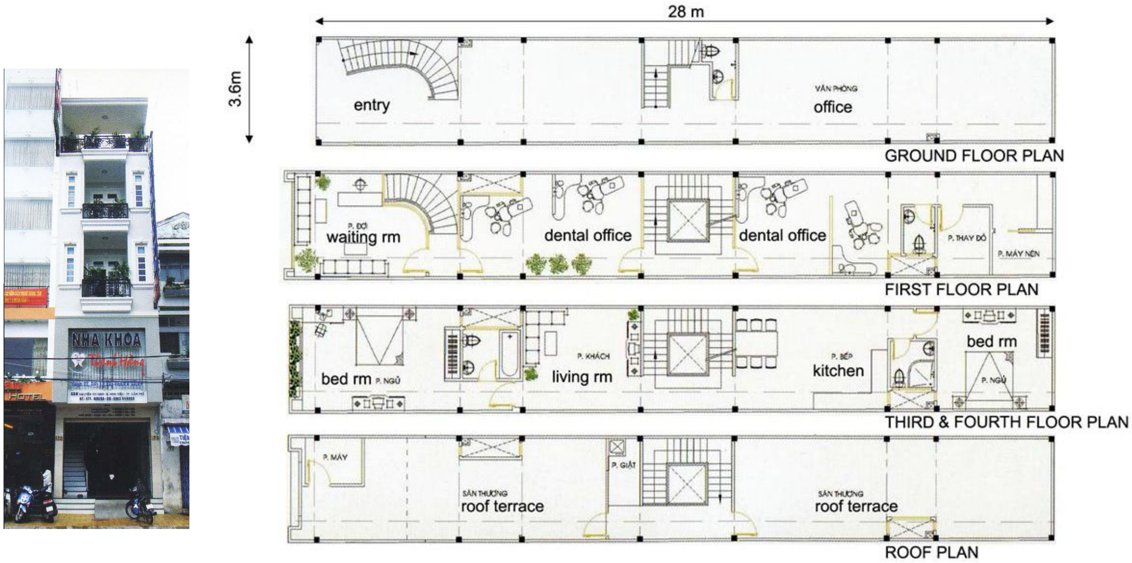


Figure 2. A street house at 138 Nguyen An Ninh Street, Can Tho City designed by architect Tran Tien Khoa. The ground and first floors of the house are used for office and dental practice while living spaces are located on the second and third floors. (Images from Trong Nhan, 2009, p.64-65).

2.2. Urban detached house: The urban detached house is a free-standing structure built in a plot with surrounding gardens, boundary fences and a private driveway (Figure 3). The detached house has up to 3 levels with at least 3 facades opened to the surrounding environment. The plot ratio of a detached house is not more than 50% (Ministry of Construction, 2009).

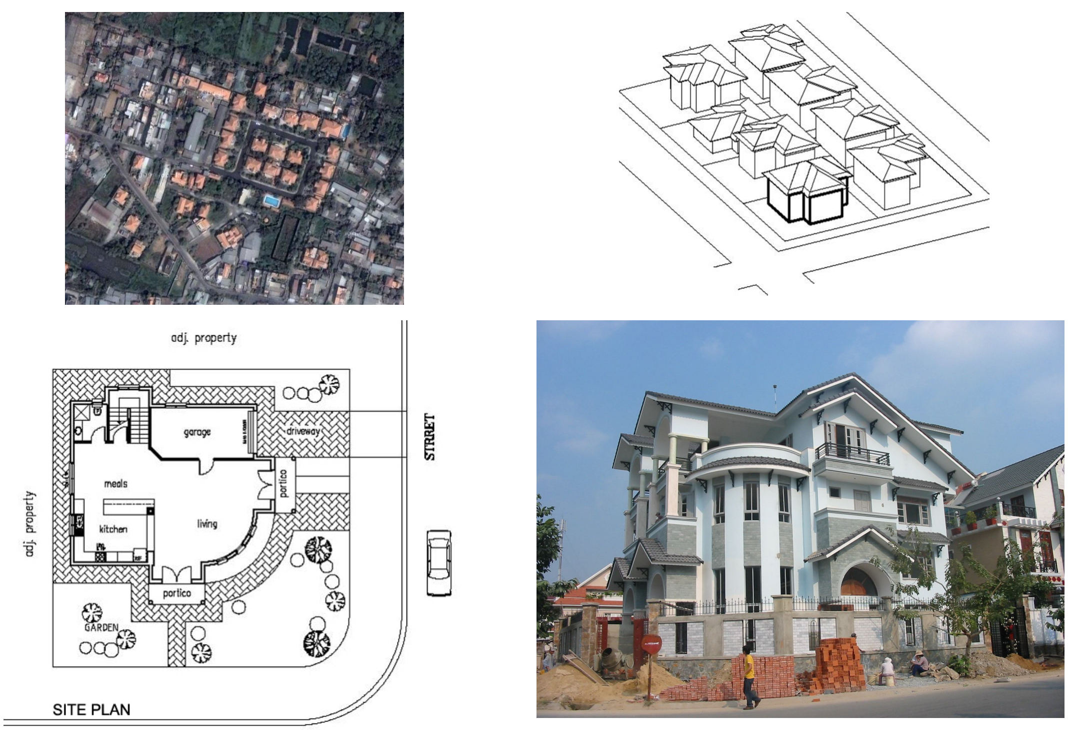
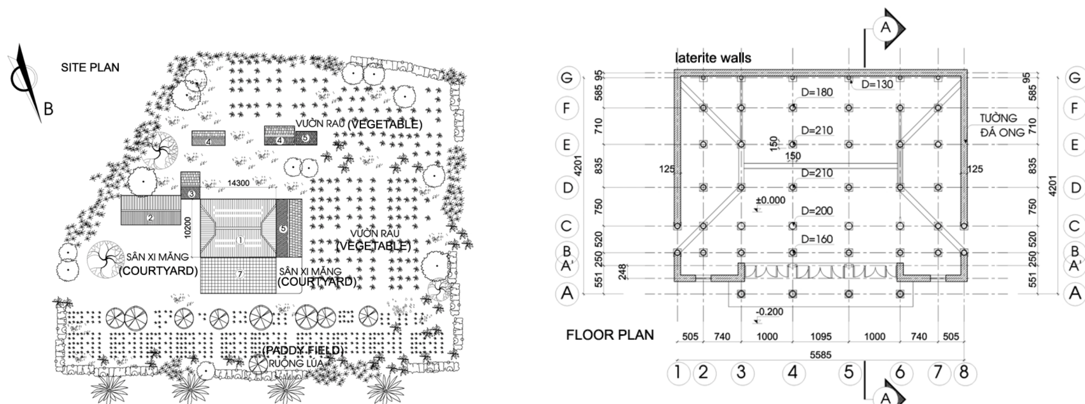


Figure 3. A typical urban detached houses located in An Phu, a new urban area of Ho Chi Minh City. The house has three floor levels with steep concrete roof. Reinforced concrete structural frame, fired brick walls with cement render to all elevations, ceramic flooring tiles are main types of construction materials. (Images by Phuong Ly during the site visit in 2009).

2.3. Apartment: The apartment is a type of housing that has more than two floor levels with pathways, staircases, and infrastructure systems used by many families and occupants (Figure 4). There are two areas in an apartment: common areas and private areas (Vietnam National Assembly, 2005). A family unit in the apartment is a self-contained design with the area of more than 45 m^2.

Figure 4. An apartment designed by SURV-Shanghai, China. Completed in 2008, in Saigon South Urban Area, Ho Chi Minh City, it includes 327 units and shops, and 273 parking places. The plot coverage ratio is 30.65%. (Images from Phu My Hung, 2005).

2.4. Rural house: The rural or vernacular house is a type of house, which has much land for a combination with other integral housing elements such as ponds, yards, and gardens (Figure 5). Through many centuries of evolution, rural houses have adapted to regional environmental conditions and culture by applying local materials and passive designs in the construction.



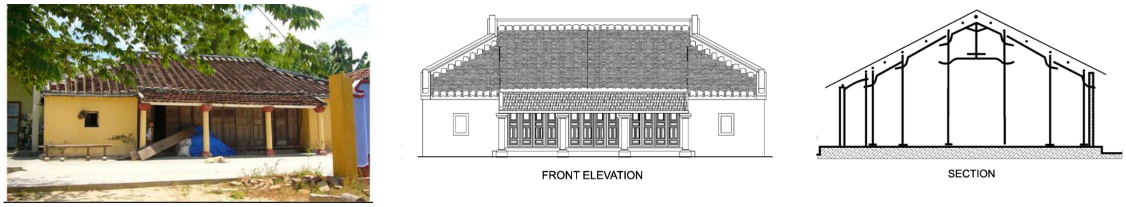


Figure 5. A rural vernacular house in Quang Nam Province integrated with surrounding gardens and rice fields. The house was built with local materials and is adaptive to climate by using appropriate built form, passive design, and site organisation. (Images fromThai, 2005).

3. Results of survey

The survey, comprising of 350 responses of random housing occupants, was conducted in 2009 in four Vietnamese major cities of Hanoi, Ho Chi Minh City, Danang, and Can Tho (Figure 1) to examine the reality of Vietnam housing in terms of its climate responsive design. The survey also explored some cultural aspects of housing design, such as a sense of place.

The SPSS version 16.0 was used to analyse the results of the survey.

3.1. Gross floor areas of housing types: Highest percentage of respondents, with 30.3%, said they live in a street house with a gross floor area of 40 to 120 m^2. There were 76 (21.7%) occupants who lived in detached houses, 23 in street houses, and 4 (1.1%) in apartment units with a gross floor area of more than 200 m^2. No respondents indicated they lived in detached houses with an area of less than 40 m^2, but 9 in street houses and 16 in apartments did. Two common gross floor areas identified were 40-120 m^2 in street houses and more than 200 m^2 in detached houses (Figure 6).

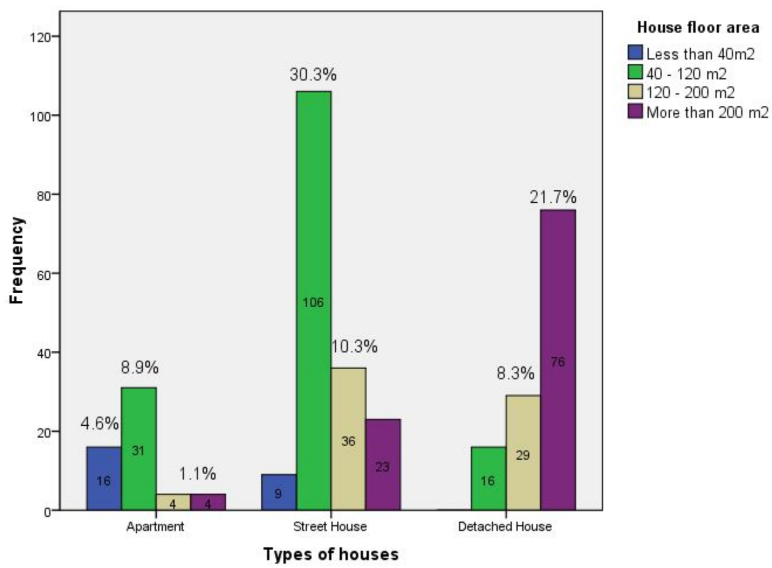
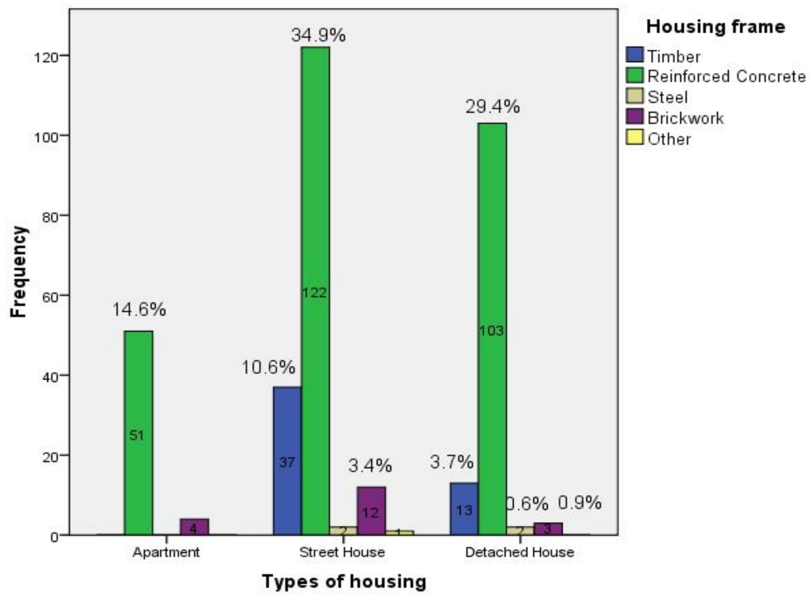
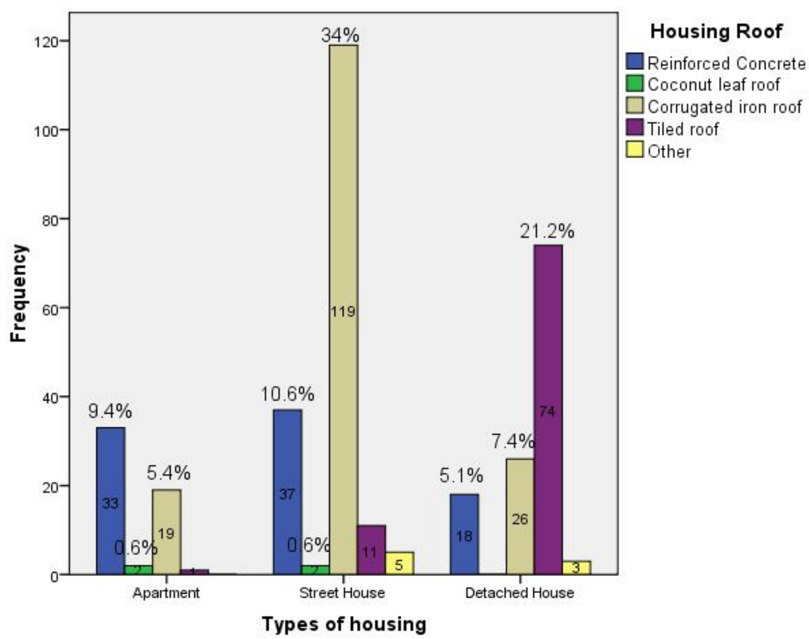


Figure 6. Gross floor area of three housing types in four Vietnamese cities in 2009.

3.2. Material use: Majority of houses (78.9%) used reinforced concrete for their structural frames including the greatest portion of street houses (34.9%), attached houses (29.4%), and apartments (14.6%). Timber was the second choice for constructing street houses (10.6%) and detached houses (3.7%). Brickwork and steel was also used for framing, but in only a few houses. The highest percentage of houses (46.8%) was roofed with corrugated iron, including 34% of street houses. Reinforced concrete was applied to flat roof structures in three housing types with percentages varying from 5.1% of detached houses to 10.6% of street houses. 21.2% of detached houses used tiled roofs.

The majority of respondents, 336 of 350 or 96%, answered that walls of their houses were made of brickwork. This material is commonly used because of its inexpensive and convenient construction in Vietnam. Similarly, ceramic tile was the first choice of flooring finishes with a total percentage of 83.1% in all housing types. Timber floors were said to be used in 6 respondents' detached houses, which accounted for 6%. 28 respondents said that their street houses were built with compressed cement tiles and fired clay tiles (Figure 7).





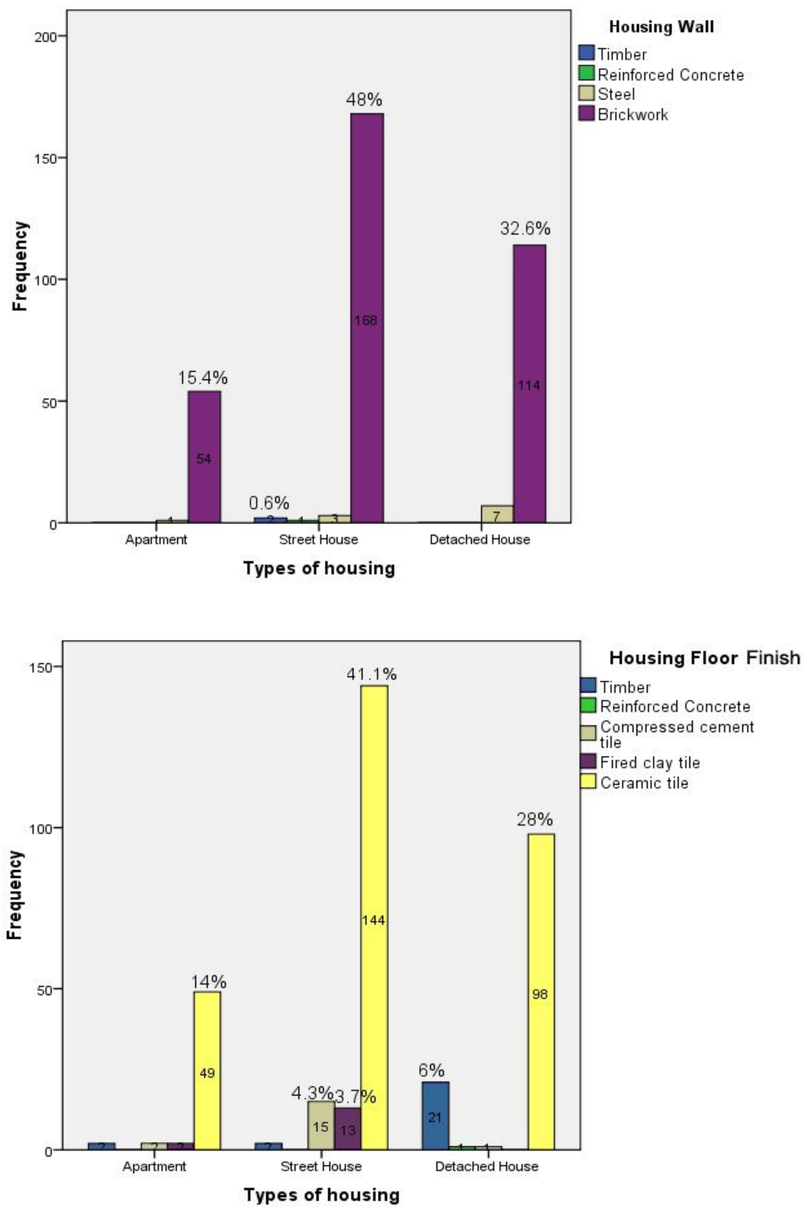


Figure 7. Materials used in three house types in four Vietnamese cities in 2009.

3.3. Thermal comfort: Most respondents (80.3%) felt comfortable in their homes while 11.7% said they were hot and stuffy and 6.0% felt cold and draughty. Only 0.3% and 1.7% of the respondents said that their houses were very hot and very cold respectively. The mean score of 2.97 reflects the fact that slightly more respondents felt hot and uncomfortable in their homes. The main reasons for thermal comfort are due to appropriate orientation of the houses, according to 240 answers (68.6%). More than half of occupants (213 or 60.9%) said they felt comfortable because they use operable windows, doors, and other apertures. There were other reasons including thermal insulation use, landscape design, shadowing from other buildings, and feng-shui principles.

3.4. Natural ventilation: Over half of respondents, 54.95%, said their houses were naturally ventilated and 34.6% said that the houses received a lot of air movement. 9.1% considered their houses were not ventilated. Only 1.1% lived with no natural ventilation at all in their homes. The mean score of 3.50 reveals that most respondents were satisfied with their ventilated houses. Most respondents (230 or 65.7%) thought adequate ventilation was due to using operable or louvered windows. Similarly, 229 (65.4%) occupants, including 108 (30.9%) who lived in detached houses, felt that their houses had an appropriate floor plan for connecting to the outside environment. Other solutions for achieving natural air movement in respondents' houses were the use of openings, courtyard, and rotating turbines.

3.5. Natural lighting and shading: Majority of home occupants (314 or 89.7%) said their houses were naturally illuminated by using windows, doors, and openings, while 173 (49.4%) had natural lighting through atriums or skylights. About a quarter of respondents (82 or 23.4%) used courtyards to encourage daylight. Only 23 houses (6.6%) did not have any means to capture daylight into the houses, including 12 street houses. 231 indicated that their houses used canopy and shading devices to control sunlight and glare. Using curtains or blinds and planting trees and vines were the second choices of nearly 50% of the total respondents to reduce glare. Accounting for 10.6% of the total, 37 houses had no solar control device at all.

3.6 Water conservation: Most respondents (329 or 94%) did not have rainwater tanks installed in their houses. Only a minimum number of street houses (12 responses) and detached houses (9 responses) captured rainwater in tanks. 93.4% of potable water was from the piped network supply. A few respondents (4.9%) used underground water for drinking and cooking and distributed mostly to street houses (11 responses). Surface water and well water were also used in homes.

3.7. Energy consideration: Only 2.6% of houses used solar hot water, including 5 detached houses, 3 street houses, and 1 apartment. Only 1 detached house (0.3% of total) installed photovoltaic panels to capture solar energy. Most respondents, 97.1%, did not know about or did not use any solar energy device in their houses.

3.8. Waste avoidance: Most respondents (85.7%) confirmed that they did not sort waste into recycled or organic types before throwing it away. Only 13.7% said their habit was to sort waste before disposal, while some home occupants did not know anything about waste disposal. Their houses possibly did not include storage facilities for sorting waste.

3.9. Sense of community: More than a half of home users (217 or 62%) asserted that they met their friends in the living room. A small portion of respondents (16.9%), who mostly lived in street houses, chose to welcome guests under the verandah. Some respondents (47) said they met neighbours in their gardens or yards and some preferred the kitchen to chat with friends. About a half of the respondents could access public transport and supermarkets within 100-800m, and 49.4% of houses were located more than 800m to the park. Approximately 20% of the houses were located near to the station and market, and 9.1% of them were close to a park.

4. Interviews of housing professionals and the discussion for guidelines

Face-to-face interviews were conducted in various areas of Vietnam in 2008 and 2009 with 14 individuals including architects, builders, local officials, and housing researchers (Table 2). These interviewees were selected based on their understanding of the current housing design and construction in the country, and their awareness of the significance of sustainability in the future housing development and retrofitting. Common themes in terms of housing design were identified, including views about existing housing, current regulations and potential solutions for sustainable housing in Vietnam, as summarised below:

Table 2. List of interviews conducted in Vietnam.

Hierarchy of Service	No	Date of meeting	Interviewees	Gender	Occupation	Professional Background
State Level	1	20 Dec 2008	Interviewee 9	Male	Engineer	PhD in Civil Engineering
	2	29 Dec 2008	Interviewee 11	Male	Architect	Master of Architecture
	3	07 Feb 2009	Interviewee 13	Male	Architect	Master of Architecture
	4	15 Feb 2009	Interviewee 14	Male	Architect	Architecture
Local Authority	5	06 Dec 2008	Interviewee 6	Male	Engineer	Civil Engineering
	6	07 Jan 2009	Interviewee 7	Male	Architect	Architecture
	7	20 Dec 2008	Interviewee 8	Male	Engineer	Master of Civil Engineering
	8	06 Jan 2009	Interviewee 12	Male	Engineer	Master of Civil Engineering
Developer	9	21 Feb 2009	Interviewee 5	Male	Engineer	Civil Engineering
Researcher	10	30 Nov 2008	Interviewee 2	Male	Architect	PhD in Architecture
	11	06 Feb 2009	Interviewee 10	Male	Architect	Master of Architecture
Architect	12	30 Nov 2008	Interviewee 1	Female	Architect	Master of Architecture
	13	01 Dec 2008	Interviewee 3	Male	Architect	Master of Architecture
	14	01 Dec 2008	Interviewee 4	Male	Architect	Master of Architecture

4.1. Interviewees' evaluation on existing housing system and discussion

4.1.1. Types of urban housing: The row house or street house structure is the typical form of urban house (more than 60%), because it is well adapted to occupants' needs and lifestyles, and enables them to work and live in the same area (*Interviewees 6, 8, 11& 12*). The second type, the detached house, has been developing in many new urban areas (*Interviewees 2 & 13*). The apartment structure is the third preference due to its small footprint in relation to density (*Interviewees 4, 5 & 9*). Most row houses in urban areas are designed and constructed based on owners' decisions, while detached houses and apartments are shaped by professionals (*Interviewees 4 & 11*).

Discussion: Mixed types of housing were seen as desirable, including low-rise and high rise buildings, to provide a diversity of spaces for changing needs. Potential passive design elements, such as topography, sun, wind, shade, and vegetation should be optimized in housing designs.

4.1.2. Housing forms and characteristics: Row houses are a traditional structure in many places in Vietnam (*Interviewees 3, 4, 7, 11 & 13*). The row house has its only access from the street-facing side and the remaining three sides are closed in by adjacent property boundaries. According to local regulations and the urban planning codes, the height (or number of floor levels) of the houses is determined by the width of the street they face. The wider the street is, the higher the houses are without any concern for the narrowness of the houses (*Interviewee 11*). They also comply with rules of setback, plot coverage ratio, overhang of balcony, and even colour use (*Interviewees 11 & 13*). These row houses fill up the sites and constitute an extremely dense urban fabric (*Interviewees 6, 8 & 12*). For detached houses and apartments, despite their smaller percentage of urban dwellings, designers can organise spaces and them adapt them to environmental conditions as they are free-standing (*Interviewee 4*).

Discussion: Multi-storied housing forms for high dense populations may be inevitable given rapidly urbanising cities. If trends continue, row houses or detached houses may need to give way to high-rise apartments to provide for more families. New apartments could be designed to provide more comfort and living qualities than row houses now. The number of high-rise condominiums should be increased. High-rise and/or compact buildings can help to reduce the use of materials and land resources in the future. Mixed-uses in these buildings, such as shops and services on lower floors and apartment units on upper floors, provide for reduced transport requirements for occupants.

4.1.3. Impacts of current housing development: The spontaneous development of row houses by private families is leading to disorder in the urban structure (*Interviewee 7*). There has been no consideration of climate responsiveness in row house design (*Interviewee 4*). Land is occupied for maximum construction rather than for vegetation.

Discussion: Despite their inefficiencies, row houses should be maintained in urban areas to respect the existing built fabric. However, design guidelines should ensure that they meet basic requirements of sustainability through such conventions as plot coverage ratio, height limits, and open space provisions for permeability and access to nature. The number of detached houses should be minimized to save open space in urban areas. Passive design should be encouraged in rural houses where services such as piped water, network electricity, and other modern equipment are not available.

4.1.4. Materials and resources for housing: All housing types have been built with reinforced concrete, including footings, frames, floors, and even steep roofs, as this kind of material is durable and robust in tropical conditions (*Interviewees 8 & 13*). Fired brick is used for walls, and glass for windows and doors. Timber is no longer preferred in new residential construction due to its cost, potential for decay and termite damage in hot humid conditions (*Interviewees 5 & 7*).

Discussion: Bamboo, rattan, thatch, rice stems, rice husks, and coconut husks are abundant in Vietnam and can be manufactured into natural building products for modern construction. In future housing, energy efficient equipment should be used to reduce energy consumption. Robust materials and structures should be considered due to increasing extreme weather events. Housing in typhoon-prone areas should be designed with braces and ties. Local durable materials, such as stabilized or compressed bricks, should be encouraged in new construction to limit the use of materials with high embodied energy such as conventional cement, fired bricks and tiles. Recycled materials should be reused whne existing buildings are deconstructed to make way for denser development. Design for flexibility should be applied so that spaces can be varied according to changing occupant requirements and building functions. A Vietnamese home should be designed as a place for working, living and other family activities.

4.1.5 Health, comfort and safety: When meeting an architect, clients usually request sufficient space for working and living with a minimum cost of construction (*Interviewees 1, 5, 8 & 12*). Some affluent owners express preferences for natural ventilation and daylight (*Interviewees 5 & 12*). For speculative apartments, clients require designers to maximise floor areas to increase sale profits without consideration of environmental issues (*Interviewee 5*). Sustainability is new to most clients (*Interviewees 10 & 11*).

Discussion: It is important to design houses that meet all occupants' requirements, such as the number of floor areas, spatial organisation, ventilation, daylight, noise control, as well as personal habits of living and working. Issues of building safety for elderly and children access, security and activity should also be taken into account. Materials which contain VOCs and radon, such as interior laminated timber and granite or clay from areas affected by radon, should be checked and avoided. Natural or passive systems should be used in place of fossil-fuel-based systems for air-conditioning and ventilating.

4.1.6. Urban infrastructure and water services: Flooding and pollution due to poor sewage systems, loss of wetlands, reduction of natural lakes and canals, and sea level rise are affecting existing and future infrastructure (*Interviewees 2 & 9*). Many wetland areas have been filled in by new urban development (*Interviewees 9 & 12*). Only a small number of houses were designed with rain water harvesting systems (*Interviewees 2*).

Discussion: Urban infrastructure should be improved to provide for health and environmental amenity. Wetlands and natural drainage systems should be conserved to avoid flooding in urban areas. More tropical vegetation should be planted and integrated with urban houses to mitigate the urban heat island effect and create the characters for a tropical region. Selecting vegetation that is native to the bioregion will save maintenance costs. Green infrastructure should be widely distributed for accessibility for mental and physical well-being. Safe public spaces with environmental amenities encourage people to come together and build a sense of community. Rain water should be harvested for household use such as landscape watering, car washing, cloth washing and toilet flushing. In some areas, rain water can be used for cooking after being filtered and treated under the sunlight.

4.2. Interviewees' views on existing legislative regulations

Due to a lack of resources and researchers, Vietnam building codes and standards have been borrowed and translated from foreign countries (*Interviewee 9*). Most codes are too general to apply and need to be more detailed (*Interviewee 1*). Major cities have their own building regulations to control and manage housing design and construction. However, there is not yet any code and guideline for sustainable housing. The interviewees emphasized the importance of passive designs for the tropical climate to minimize sun and rain impacts while increasing natural ventilation, daylight, and shading for windows. However, their responses indicate that, in general, practitioners in Vietnam (as elsewhere) are not very sophisticated in their knowledge of sustainability and sustainable design. The transformation to better design will not happen on its own. It became clear that a green code or design guidelines and exemplars for retrofitting and new design of housing in Vietnam is needed (*Interviewees 1, 2, 8, & 9*). The guidelines and codes should address the following issues:

4.2.1. Cooling: Solar radiation should be controlled and reduced by using roof overhangs and window canopies. Building plans should be designed with single room depth for natural cross ventilation. Balcony and loggia can reduce solar gains and provide a sense of community. Verandah and porch are appropriate for air circulation and providing shade. Operable windows with appropriate window size and location can be integrated with a wind wall and vegetation to increase natural ventilation. Courtyards should be used in row houses and apartments to capture daylight and ventilate the houses using the chimney effect. The main spaces should be located on the south and the north of buildings, and service spaces such as toilets and baths on west-east orientations.

4.2.2. Energy: Solar panels should be installed on roofs for hot water and energy as Vietnam has a high intensity of solar radiation.

4.2.3. Vegetation: Green roofs and green walls can be used in new construction and building retrofitting. In particular, a roof garden is suitable to row houses which usually have terraces on flat roofs.

4.3.4. Waste avoidance: A place should be dedicated for household waste sorting, especially the organic waste bin which can be transformed into a rich fertiliser for garden use by using worm containers.

4.3.5. Waste treatment: A place amongst groups of houses should be provided for greywater treatment. Consider a living machine for aquatic plants which can clean the greywater from a block of housing.

5. Conclusion

Sustainable housing development in Vietnam would reduce environmental loads and increase the quality of living and health for inhabitants and ecosystems. The transition to sustainable housing will require design principles appropriate to the Vietnamese climate and culture, as thus modern development has been detrimental to both. This survey of current housing, and in-depth interviews with many housing design professionals, will provide the basis for green design guidelines that suit cultural and consumer preferences. The guidelines will be devised to integrate construction and retrofitting with the climate and culture, health and safety issues, resource minimization, energy reduction, and waste avoidance. The next stage will be to identify exemplary and design concepts using natural systems that can be retrofitted into Vietnamese urban buildings and landscapes to reduce fossil fuel dependency and increase resilience in the fact of climate change.

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