Topic: T1.5 Indoor Environment Quality Health and Wellbeing

Post-occupancy evaluation of architecturally-designed low-income housing in Ahmadabad, India

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Abstract: This paper presents post-occupancy evaluation of low-income houses that have been built through the DMU: Square Mile India Programme in Ahmedabad, India. Questionnaire and interviews were conducted which elicited information on respondents' socio-cultural and environmental experiences in the new houses compared to the existing dwellings in the community. Findings include: 1. increased expectations and higher demands for space and facilities in the new houses, 2. discontent with integrated courtyard/ open spaces, 3. prioritising flood protection over environmental quality and thermal comfort conditions in the existing houses and 4. Significant change in the perception of social status of families in the new homes. The findings highlight residents' need for adequate sleeping area, thermal comfort, safety from animals and security. These aspects must be critically considered in future design of similar houses. The paper produces empirical evidence on users' perception that will provide better knowledge and understanding to the designer and policy-makers to identify important factors to improve residents' quality of life in a low-income housing context.

Key words: thermal adaptation, thermal comfort, skin temperature, hot-humid region (no more than five keywords)

1 Introduction

Sustainable human settlements - a fundamental feature of UN's Sustainable Development Goals (SDG), SDG 11 Sustainable Cities, is one of the largest challenges we face. More than 900 million people worldwide live in poor urban settlements which can mainly be found in cities of the global south [1]. India has a significant number of their urban population living in low-income housing characterised by overcrowding, poor infrastructure, lack of ventilation, light, sanitation and water-supply facilities [2]. These living conditions are further aggravated by rising temperatures due to global warming having a serious detrimental effect on people's health with increased risk of sickness and mortality, mental impairment, reduced productivity and economic losses [3].

The characterisation of heat- stress in poor urban settlements in global south as a result of global warming, poor environmental quality and unsustainable construction methods/ materials, has scarcely been explored. Its consequences on human health also remain unexplored even though between 1.8–4.1 billion people are potentially exposed to heat- stress due to lack of access to cooling/ ventilation, mostly located in India, South-East Asia and sub-Saharan Africa [3].

Therefore, it is extremely important to address these vulnerable settlements where populations lack access to suitable indoor comfort and to prioritise climate adaptation efforts and policies to implement the SDGs. Significant lessons can be learnt from experiential knowledge of housing and user assessment for

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reducing the vulnerability of the poor settlements to climate change.

This study aims to integrate the socio-cultural and environmental experiences in a low-income housing through interrogating how the socio-economic conditions shape the design and use of homes. It intends to address this under-researched area by exploring the day-to-day practices, overheating and thermal discomfort in a flood-affected low-income community in Ahmedabad in India. A number of new houses, designed by a local architect, were built in the community through the DMU: Square Mile India Programme. The community identified 50 houses that were in most need of upgrading. In total 4 homes had been completed at the time of the study with a further 6 planned for delivery. The homes are in a community land trust so residents are not able to sell properties on after completion. In discussion with the community a lottery system was was developed to select which homes would be developed first and a fixed cost per home of approximately £5000. Each home was designed in consultation with the resident and defined budget. The intention of the design was to enable the future expansion of homes where possible recognizing the needs of residents will change over time.

The living conditions in these households and working practices of the inhabitants in terms of how the building and its internal-external spaces are used, are explored through semi-structured interviews and monitoring (immediate measurements). The findings from the study will provide an in-depth account of how the relocation of the flood-affected households have altered the dwellers' household routines (health and well-being, comfort, satisfaction and working practices) and their overall living conditions compared to those living in poorly-built, existing houses that have been built without any design in relation to comfort needs and occupant satisfaction.

2 Methodology

2.1. Study area

As per the Köppen climate classification (BSh), Ahmedabad has a hot semi-arid climate with three main seasons: summer, monsoon, and winter. The climate remains dry throughout the year, except for the monsoon season. The hottest temperatures are observed throughout March and June. An average maximum temperatures of 45^0C in the pre-monsoon summer months of March-May makes Ahmedabad one of India's hottest cities with heat posing a significant public health challenge [4]. During November to February, climate is generally very dry with the average maximum and minimum temperatures being 27°C and 15°C respectively. A mild chill is observed in January from cold northerly winds. Monsoon is observed between mid-June to mid-September with infrequent heavy torrential rains.

The study area is located on the outskirts of Ahmedabad, India at 22°59'58.6"N and 72°38'40.0"E which is 8.41 km south-east of Sardar Vallabhbhai Patel International Airport, Ahmedabad. It is called the Loving Community named by the Gandhi Leprosy Seva Sangh. The Ghodasar Canal – a sewerage canal flows on the east of the community. The community was formed in 1968 after the land was provided by the Government of Gujarat to accommodate leprosy-affected people from all over India who were socially excluded due to the contagious nature of the disease. The community still has many leprosy-affected people, although the spread of the disease has been stopped long ago. The community has 125 houses with a population of approximately 500 people.

The community has three different categories of houses. First category (Old-Houses) are the houses that were built in 1968 when the community was established. The second category is houses those were newly built by the residents themselves and the third category (DMU-New-House) is the houses that were built under the DMU: Square Mile India Programme. This study reports findings from five Old-Houses and three DMU-

New-Houses. The houses are named as Old-House_01, Old-House_02, DMU-New-House_01 and so on. Examples of the Old-Houses and DMU-New-Houses can be found in Figure 1and Figure *2*.

a. b. c.

Figure 1. a., b., Interior of existing Old-Houses without any window openings, c. Exterior of Old-Houses

a. b. c.

Figure 2. a. Front courtyard in the DMU-New-House 1, b. New-House 2, and c. Foldable main opening in New-House 2.

2.2. Measurements

The data collection involved questionnaire surveys, interviews, visual inspection, photographic survey and thermal comfort survey alongside environmental measurements in all three new houses and five existing houses. Data included air temperature, relative humidity, wind speed and mean radiant temperatures.

2.3. Questionnaire survey and interview

Questionnaire surveys and interviews were conducted to understand the thermal comfort perception, window-opening behaviours, daily house-hold activities, spatial uses, a comparison of previous households to the new ones (DMU-New_Houses) and overall satisfaction of the residents.

3 Results and discussion

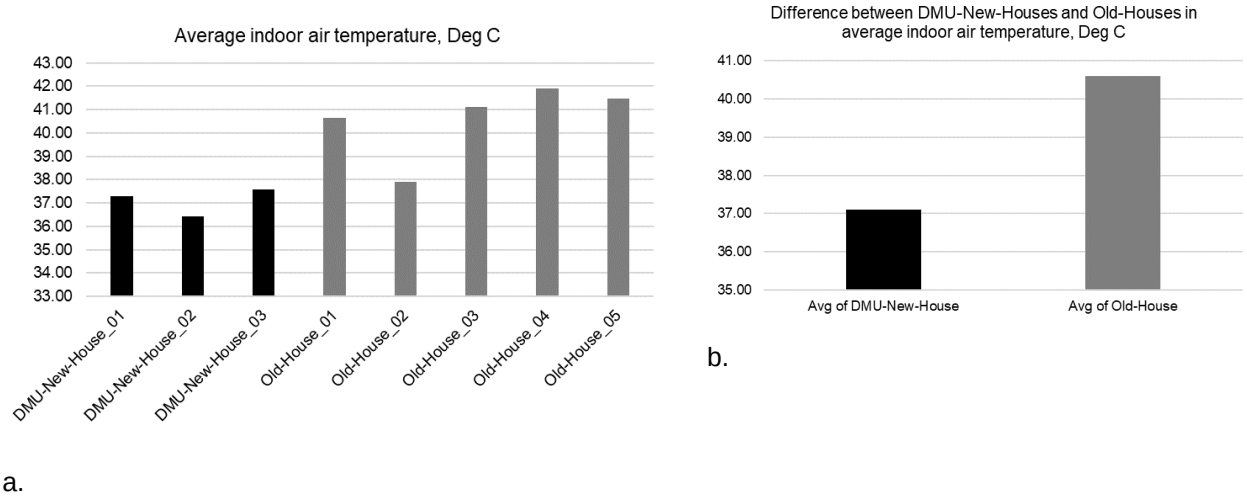
3.1. Socio-cultural impact on thermal comfort

Culturally and traditionally, the people in the region are accustomed to stay outside throughout the most part of the day and sleep in the courtyards or terraces at night. The reason behind this mainly climatic as it is not possible to fully modify the indoor environment through design and building material. Therefore, people

take it very naturally to come out of the house and stay outside in a nearby open field, under the shade of a tree, whenever it is uncomfortable inside the house. Even at night, it is completely normal for men and women to sleep in the open premises outside their house, for thermal reasons. In the questionnaire survey, 86% respondents chose 'go outside' as the first option while feeling hot indoors.

Due to the hot-dry nature of the climate during the summer, the air temperature reaches over 40^{0}C during day-time. After the sunset, the heated surfaces dissipate the stored heat towards the cloudless sky and becomes cooler. In this climate, if the diurnal range is not properly considered into building design in the selection of material as well as the provision for natural ventilation, the building interior can become uncomfortably hot during the sleeping hours when outside air temperature may have reached a tolerable level. Therefore, it is more sensible to sleep outside if this is socially and culturally acceptable. For the reason, people in a low-income area tend to stay indoors only for the private activities that includes cooking, eating, watching tv etc. During the interview, 8 out of 8 dwellings mentioned sleeping outside during the night.

The environmental conditions in the existing houses were found to be uninhabitable. Figure 3(a) shows the average indoor air temperature in the new and old houses during the survey hours. Except for Old-House_02, all old houses have an average air temperature over 40.0^{0}C. Figure 3(b) shows the average air temperature in the old houses is 3.5^{0}C higher than the average air temperature in the new houses which is a significant difference.



a.

b.

Figure 3. a. Average indoor air temperature in new and old houses, b. Difference in average indoor air temperature between new and old houses

As per the questionnaire survey, during the survey period 50% people felt hot, 14% warm, 36% people felt neutral. People feeling hot or warm were dwellers in the Old-Houses. On the other hand, dwellers in the DMU-New-houses were 100% neutral.

3.2. Socio-cultural impact on the courtyard

Courtyard is an inseparable element in the built environment in this particular climate. It is the centre of social activities in a house. In the Loving Community, women also use the courtyards for any income generating activities, such as, sewing and other cottage-industry-related activities.

Also, the environmental features of courtyard as a mediating space is well-known. It works as a thermal buffer for the flanking rooms and works as air-scoop to allow natural ventilation inside.

Therefore, to facilitate natural ventilation and preserve social contacts, a courtyard was incorporated in all three new-built houses. Out of three, two houses had a backyard in addition to a front courtyard, whereas the

other only had front courtyard due to lack of space. The existing properties all currently have front courtyards which are used for social activities and sleeping. The backyards were incorporated to allow privacy and provision for washing clothes and utensils as well as sleeping should the residents desire. Private toilets and bathing facilities inside the house are still a new thing in many rural areas in India. Traditionally, many villages did not have any private toilets, not even public ones. For women, it is culturally uncomfortable to enter toilets through a public space or a front courtyard. This is the current layout in the existing houses with entrance to toilets off the front courtyard. Therefore, these backyards were provided to give access to the toilet and bathing facilities, especially for the women of the house.

The other essential reason for including the backyards is cross-ventilation. In a high-density, low-rise area, it is the only way to allow enough cross-ventilation through the interiors. Large openings are incorporated to enhance cross-ventilation which can be folded aside to open the interiors completely to the outdoor. In the absence of any planning and building regulations that consider the environmental performance of buildings and the wider built environment, the community houses are being converted by the residents themselves into 2-3 story structures within the tiny plots without any provision for natural ventilation. Whereas, the architecturally-designed DMU-New-Houses responds to the socio-cultural and environmental requirements of the residents.

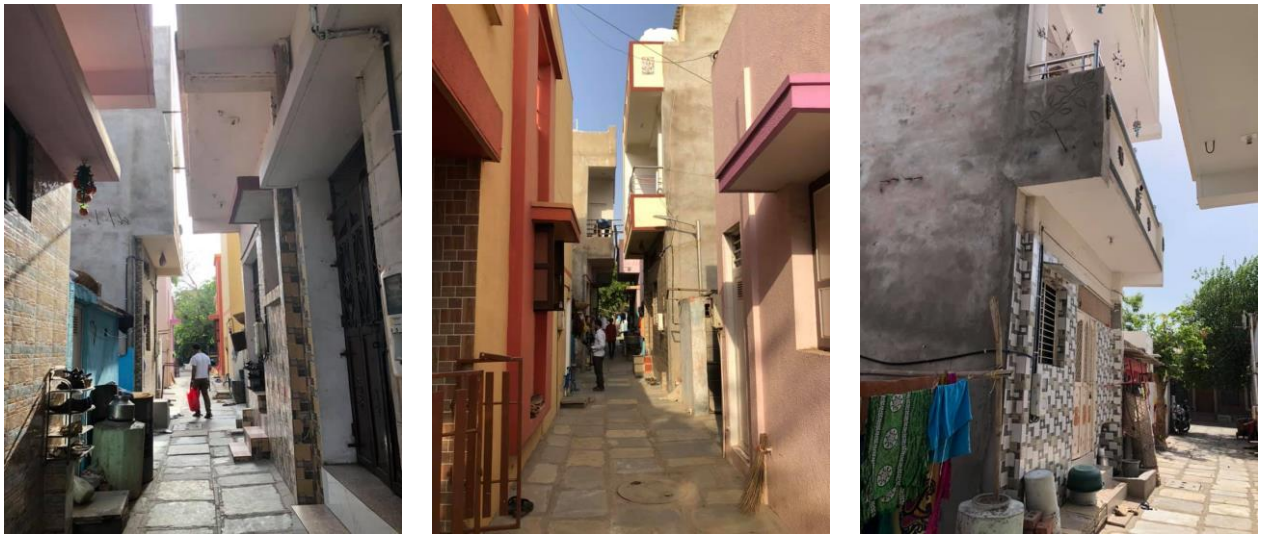


Figure 4. The community is rapidly converting into a high-density one without proper cross-ventilation and solar access

However, from the interviews, none of the residents were happy about the courtyard spaces both in the front or the back of the houses. Although they appreciated the social and functional value of the courtyard space and they used this space in their previous homes, to them it was more important to have additional indoor space rather than a semi-outdoor space where they could store more personal belongings.

Resident of the House 2 mentioned, she would like to convert the front courtyard (the only courtyard in the house) into a kitchen after keeping a minimal space for entry. Furthermore, she would like to reduce the front opening and possibly replacing the folding door which in her view will be unable to protect from the driving rain during the monsoon. Although she uses the current courtyard for income generating activities as well as for socialising, she finds the new dwelling to be very small for six people. However, in her opinion, comparing the size of the new dwelling with previous one, she felt it had a similar amount of space despite it being nearly twice the size. It may be the fact that with the provision of the new house, the social status and expectations of the dwellers may have changed and therefore they demanded more space. The resident complained about lack of storage space and sizes of the toilet and bath to be too small.

Regarding comfort, the upper floor was considered to be too hot. The main reason was conduction heat gain through a thin layer ferro-cement slab. Residents were supposed to apply a layer of white tiles on top of the ferro-cement slab which was still undone. However, no building simulation study was conducted to review how the performance of the composite roof would improve after adding the tiles.

Resident of House 1 was slightly unhappy with the backyard and used the front courtyard for sleeping. Her complain was quite unusual that wind blew in dirt in the backyard. As a single dweller in the house and due to poverty, she has minimal belongings to store in the house. Therefore, space was not an issue for her. However, she had several relatives visiting her during the time of interview. It seems, the new houses became a symbol of social status for the residents. These people who were socially neglected for a long time, finally had something to take pride on.

Similar to the resident of House 2, residents at House 3 also complained about size of sleeping area and the level of privacy. They would prefer an additional indoor space instead of the backyard. The front courtyard is a sleeping space for the male in the family and a socialising space for women in the evening. The residents were not convinced that the new house provided more space compared to their previous accommodation. They would prefer to divide the living/ sleeping room into two separate rooms to allow privacy for the women. It seems, it is common to have visitors for the new houses for night stay. Again, it shows increased social prestige and acceptance for the new house dwellers.

3.3. Flood-prevention vs indoor environmental quality

The community gets flooded every year during the monsoon during the periods of heavy torrential rains mainly due to inadequate drainage resulted from unplanned growth of built-environment on surrounding floodplains, poor waste management and clogged drainage that are common reasons for localized floods in poor urban settlements [5]. The existing Old-Houses has a ground floor that is lower than the street level and therefore, flood water enters these houses easily. From the discussion with the dwellers, it was found that flood water generally reaches above 0.5m inside the house making house-hold activities completely impossible. The dwellers are forced to take shelter in the community centre until the flood water is gone. While discussing about their priorities in the old-Houses, all inhabitants identified flooding as the most pressing issue in their houses.

4 Conclusions

The findings of this study suggest although end-users were generally satisfied with building design features and quality of the finishes, they expressed dissatisfaction with lack of sleeping area and storage space. It was evident that as the demand for basic services (such as flood-prevention and thermal comfort) were met, the dwellers' aspirations shifted towards higher social aspirations as also found in other studies [6]. There also seemed to be a lack of understanding of the design intentions of being able to expand the homes in the future despite those possibilities being developed by the architect. Significantly the value of a courtyard space was not appreciated by the residents despite it providing a more comfortable internal environment and the possibility of a more private area for activities including sleeping. This poses significant challenges for the community going forward. This is because on some plots where residents do have financial means they have rebuilt homes without courtyards and to a much higher density. The desire to develop properties to this level of density has been expressed by residents of the new homes. In addition, in these instances air conditioning has also been installed on homes. The high level of density that could arise would significantly increase the need for air conditioning while reducing access to natural light. This suggests that even when appropriate design solutions that provide passive solutions to providing comfortable indoor environment that do work are delivered, without additional work with residents on the value of this approach it is unlikely the benefits will be

retained in future modifications. It is recommended that both further work with the community to understand the benefits courtyards and more appropriate options for extending homes is undertaken.

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