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Findings from householder survey in Bawana housing development, Delhi

Case study report

Rajat Gupta, Sanjoli Tuteja,
Pratibha Ruth Caleb, Megha Behal,
Jesus Salcedo.

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MaS-SHIP

Mainstreaming Sustainable
Social Housing in India Project

OXFORD BROOKES UNIVERSITY
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Executive summary

The Government of India aims to construct 12 million social housing dwelling units through the Housing for All by 2022 programme. The UN Environment funded 'Mainstreaming Sustainable Social Housing in India project '(MaS-SHIP) seeks to identify what the impacts and benefits of housing production at such a massive scale could be, by promoting the use of sustainable building materials and systems in social housing developments. However, this is not an easy task in an inherently data poor environment. To address this challenge, MaS-SHIP has adopted a field survey-based approach wherein primary data are gathered through interview based questionnaire survey, from key stakeholders of social housing developments, including, developers, practitioners, building material manufacturers and social housing residents. Five social housing case study developments across three different climatic zones of the country were identified, and about 150 households were surveyed at each location to gain insights about the experiences of residents living in a social housing development.

This report describes the methodology and learnings from a field survey of 149 social housing residents in a housing development for construction workers in Delhi (Bawana housing development), constructed using modular perforated bricks and flyash. The purpose of the resident/householder survey was to gather subjective feedback from residents about their perception of the indoor environmental conditions (indoor temperature and air quality) in their homes during summer and winter, along with aspects of maintenance and upkeep of the development, familiarity with the building materials, and access to basic day to day necessities around the development. To undertake the householder survey, the MaS-SHIP team collaborated with a local architectural school to carry out these surveys. The gathered data were analysed and various aspects cross-related to better understand the existing indoor environmental conditions in these dwellings during summer and winter periods.

Although the building materials used in this social housing development were low cost and environment friendly, the householder survey revealed that indoor comfort was perceived to be (just) bearable during summer and winter. While 12% of respondents rated their indoor conditions as 'satisfactory' in summer, the same proportion rated it as 'unsatisfactory' in the winter. Air inside dwellings was perceived to be still by one-third of residents, though still air was desirable in winters. The survey also helped to reveal critical factors that determine the acceptability of building materials from the householders' perspective. The factory finished exposed brick work used for the wall may have helped to reduce the initial construction cost, but nailability of the walls emerged as a major concern for the residents, since the wall materials did not allow residents flexibility of making basic alterations to the interiors. The development also lacked in maintenance and cleanliness of the buildings and common areas, as well as open areas and streets. The study revealed an urgent need to establish a maintenance mechanism to improve the health and hygiene of the residents.

1. Introduction

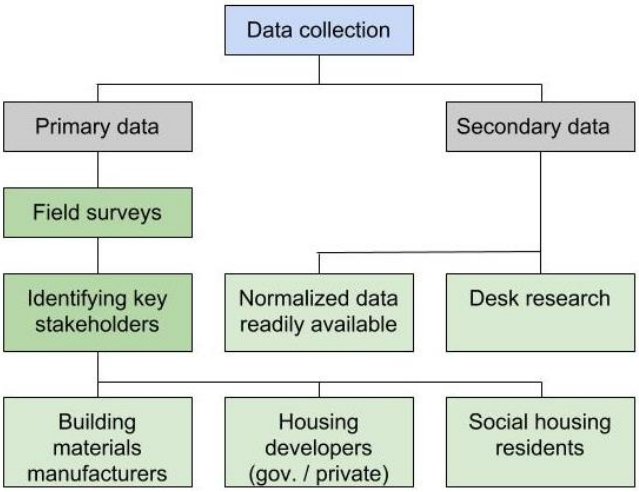
The urban housing shortage in India is currently estimated at 10 million, more than 95% of which pertains to low-income groups. Through its "Housing for All by 2022" mission, the Government of India intends to close this gap by aiming to construct 12 million housing units over the programme duration through a combination of slum upgrading projects in partnership with the private sector, direct government-led housing delivery, a credit-linked subsidy scheme as well as support to beneficiary-led construction. Since housing is, by definition, an energy and material intensive sector, this will require not only human and financial resources at an unprecedented scale, but natural ones, too. This represents both a grave danger in terms of environmental degradation, but also an opportunity for introducing life-cycle thinking into the building sector and promoting economic inclusion for millions. But first, a number of difficult questions require a scientific answer.

"Mainstreaming Sustainable Social Housing in India project (MaS-SHIP)" is a UNEP funded two-year research project that aims to identify what the impacts and benefits of housing production at such a massive scale could be – for our environment, our economy, and our communities – providing a methodology for identifying the most optimal solutions. To achieve this objective, the project is producing two major outputs.

- Sustainability Index (SI) to evaluate building systems based on a set of attributes (indicators) developed in close consultation with the Government's Systems Sub-mission under Housing for All, led by the Building Materials and Systems Promotion Council BMTPC, as well as India's leading experts in the field.
- Decision Support Tool (DST) which will provide guidelines at the conceptual stage of housing projects to enable the adoption of sustainable building practices by housing providers such as government bodies, private developers, and individual households.

There is lack of data pertaining to the sustainability parameters and attributes for assessing the sustainability of social housing. Hence in this project both primary and secondary data was collected to develop an empirical data base not only for the project but to provide a base for future research as well (Figure 1).

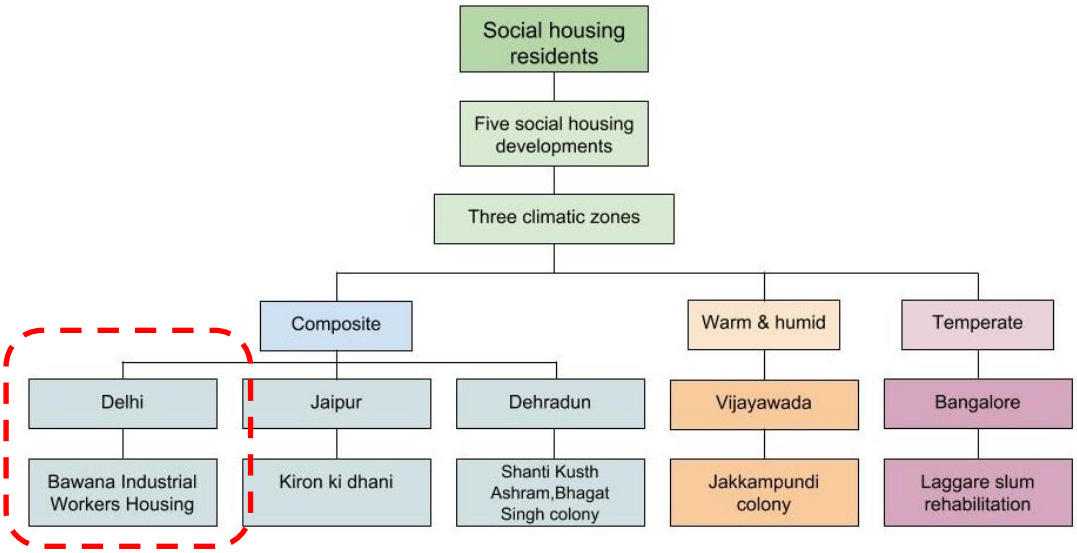
Figure 1: MaS-SHIP data collection methodology



The primary data collection was done by conducting questionnaire surveys to gain direct first-hand insights from the key stakeholders of the social housing i.e. developers (both government and private), building material manufacturers and social housing residents.

For gathering data from the social housing residents, five social housing developments were selected on the basis of their geographical location (climatic zone); type and scale of the cities in which they are located; share of urban housing shortage and the Average Annual Exponential Growth Rate in the state; and also on the basis of their ranking base on the completed social housing projects under the most recent central government programme (WP3 report). Figure 2 shows the five selected social housing developments based on their location and climatic zone.

Figure 2: Social housing case studies



A questionnaire-based survey was conducted by visiting each of the selected developments with an aim to gather data to access the current state of social housing in India and gather first hand insights of residents' perceptive of the environmental, social and economic sustainability factors in these social housing developments. Nearly 150 households were surveyed at each location during the months of September-October 2017. This report presents the findings from the field survey conducted for one of the developments located in Delhi, representing the Composite climatic zone of India.

The report is structured as follows

1. **Introduction**- This section provides a brief background of the MaS-SHIP project, along with its aims and outputs. The overall data collection methodology adopted for the project and the rationale for conducting the case study of five social housing developments across three climatic zones of India is also provided.
2. **Case study overview**, the basic details of the Bawana housing for industrial workers at Delhi are highlighted in this section. The details about the location, type of dwellings, construction materials used and demographics of the development are provided.
3. **Methodology** section explains in detail the process adopted for conducting the householder survey across the five different locations. A list of the survey questions covering the various aspects of a social housing development is also provided.
4. **Insights from the householder survey-** based on the methods defined in the previous section the gathered data is analysed individually and various aspects are cross related wherever required.
5. **Summary of findings** - The overall findings from the data analysis is summarised in this sections and critical aspects that need to be addressed from are highlighted.

2. Case study overview

Over 16, 000 industries shifted from various parts of Delhi, to the 760-hectare complex set up at Bawana Industrial area in North-West Delhi, after the Supreme Court's order to relocate both polluted and non-polluted industries away from the city. The Bawana housing scheme, developed by DSIIDC (Delhi State Industrial and Infrastructure Development Corporation Ltd.) was constructed as a part of the Rajiv Gandhi Housing scheme primarily to provide shelter for industrial workers and other Economically Weaker Sections (EWS). The development is a typical example of habitat relocation of residents living in informal settlements in the heart of the city to the outskirts.

The housing development is spread across 37 acres (~15 hectares) having a high density - about 300 dwelling units per hectare. A mix of 2, 3 and 4 storey exposed brick buildings, housing a total of 4348 dwelling units, are spread across in a rectangular layout separated by paved pathways and courtyards.

Table 1: Case study overview

Category	**Case study**
Location	Delhi
Name of the development	Bawana Industrial workers housing
Government scheme	The Rajiv Gandhi Housing Scheme
Occupancy	11 years
Target group	Economically Weaker Section and Industrial workers
Distance from city centre	30 km
Number of dwelling units	4348
Carpet area of each dwelling (sq. ft.)	Type I = 263 Type II = 297 Type III = 311

Cluster planning was adopted in the housing development, to provide organised open spaces and green areas in the form of courtyards, but proper maintenece and upkeep of these spaces is missing. All the dwelling units comprise of minimum two rooms and confirm with the minimum standards of area prescribed by the government for EWS housing. Each unit is provided with a covered balcony and the required minimum fenestrations. The building blocks were oriented so as to reduce heat gains from direct solar radiation and enhance natural ventialtion. Figure 3,4 and 5 show the typical layout of the threee different dwelling units (DU) at Bawana housing development.

Figure 3: Typical floor plan-DU type -I

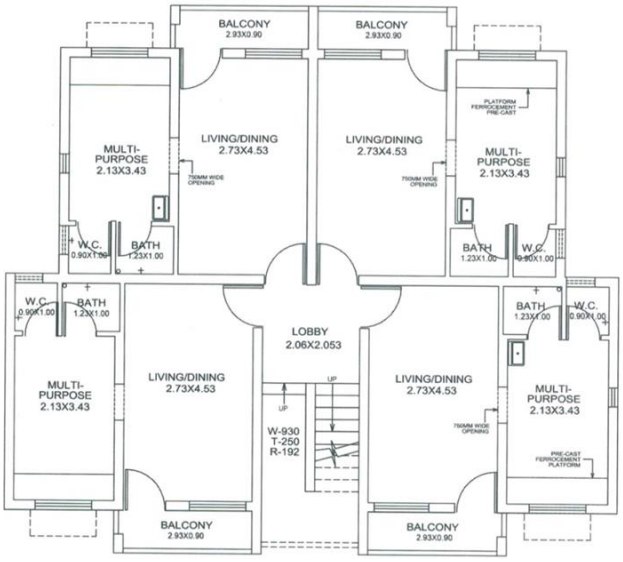


Figure 4: Typical floor plan- DU type-II

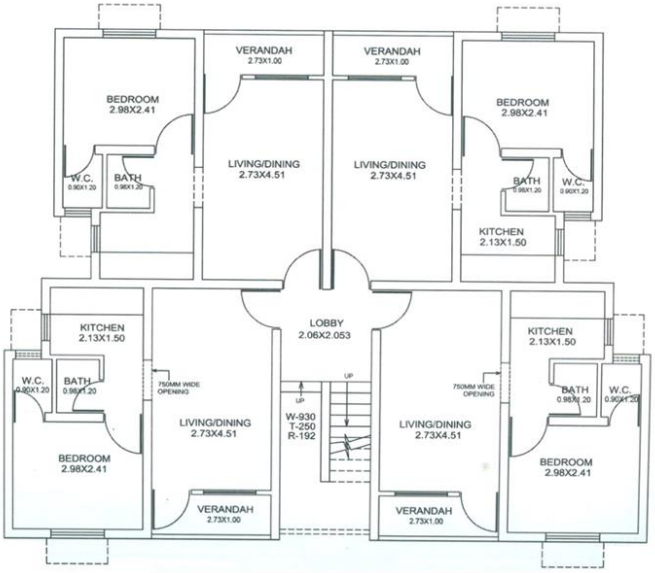
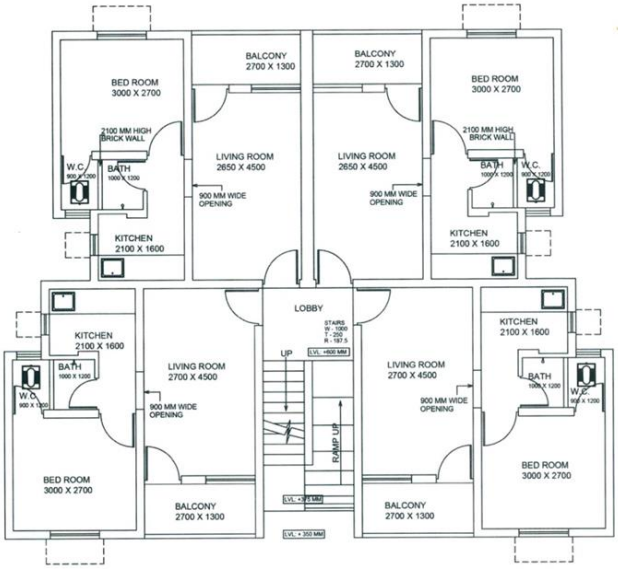


Figure 5: Typical floor plan-DU type-III



2.1 Building materials and systems

The Bawana housing complex was intended to be developed as an economical, environment friendly and energy efficient housing for the industrial workers and Economically Weaker Sections. It is one of the first social housing developments in India which was built using alternative materials and systems.

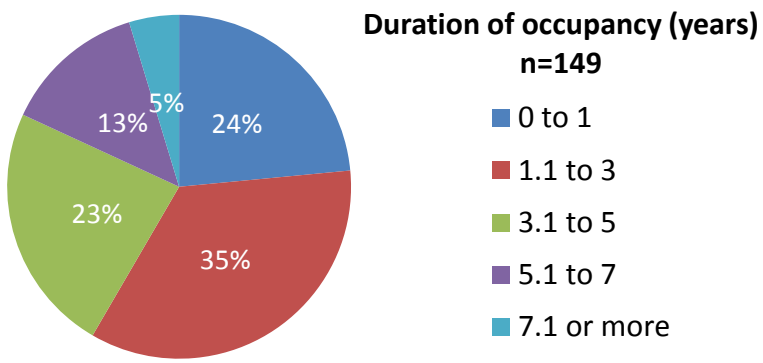
Table 2: Building materials used in Bawana housing

Foundation	• Under-reamed pile foundation
Superstructure	• Single brick thick load bearing wall using combination of modular FalG & mechanised modular perforated bricks • Precast Ferro cement steps for stairs • Precast Ferro cement shelves for kitchen • Precast R.C. sunshade • Use of flyash with cement mortars
Roof / Floor slab	• Precast RC Plank and Joists • Cast in-situ waist slab in RCC
Doors and windows	• Second class Teak wood door frame • Second class Teak wood door window frames and flush door • Grill in ventilators and windows • Pre-cast lintel
Others	• Whitewash on walls • Precast Ferro cement sunshade

2.2 About the households

At the time of the survey the houses had been occupied for up to 11 years with only a few of the original residents still living there. Over the years the industrial workers moved to different location and put up the houses on rent. Most of the residents surveyed were living on rent. Of the 149 surveyed households about 35% had been occupied for up to three years. About 24% of the dwellings had been occupied for as less as one year. Nearly similar percentage of households had been occupied for up to five years, whereas few households had been occupied for over five years (Figure 6).

Figure 6: Duration of occupancy



In terms of number of residents, the survey revealed maximum households having about four members (Figure 7). However, a significant number of dwellings were also found having occupancy of five or more members, making the living congested (Figure 8).

Figure 7: Occupancy of surveyed households

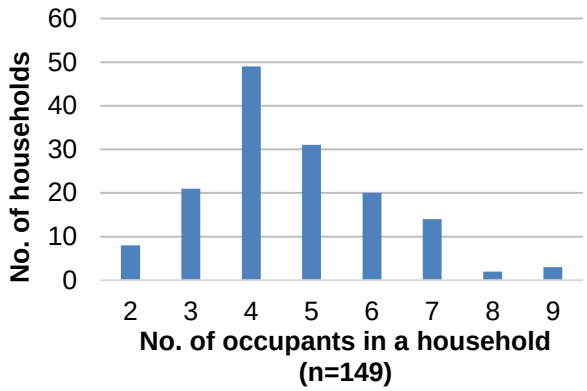


Figure 8: Interior of a DU at Bawana

The surveyed households had 58% of residents aged around 19-58 years, and most of them would spend about 10-14 hours at home during the day. 24% of the residents were aged between 3-18 years which would mean mostly children and the amount of time they spent at home would vary from 14-20 hours. For some it would also go up to more than 20 hours depending on their age and their time spent at school or generally outside their homes (Figure 10).

Figure 9: Age group of residents

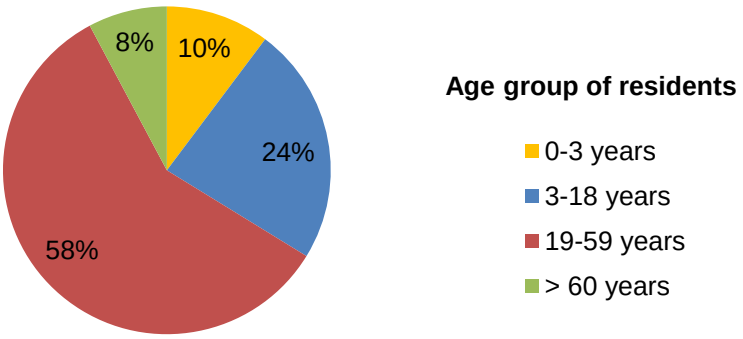
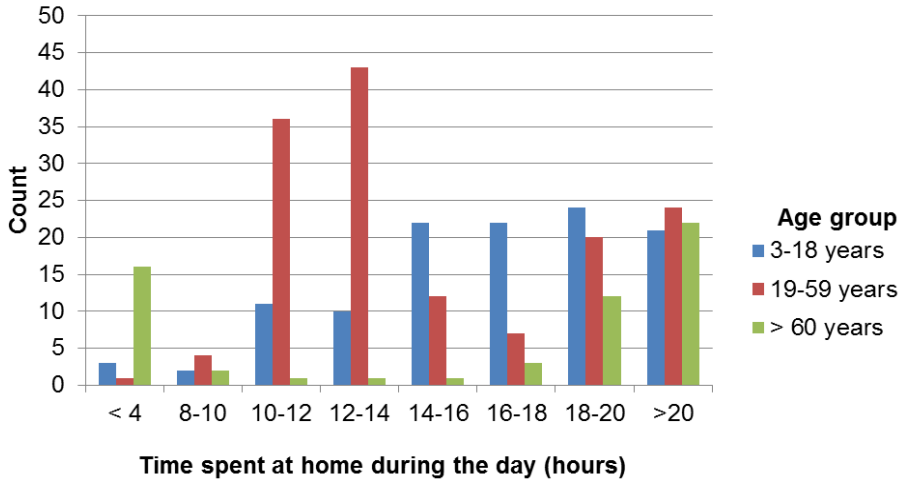


Figure 10: Time spent at home during the day



3. Methodology

3.1 Questionnaire survey

In order to collect a mix of quantitative and qualitative data, interview based questionnaires were conducted based on structured questionnaires designed specifically for gathering feedback from the householders of the social housing developments at the five selected locations in India. The questionnaires went through several rounds of iterations which included review by the technical reviewers of the project and industry experts.

The householder survey provided a snapshot record of the perception of social housing dwelling units from the residents' perspective. The survey questionnaire consisted of 24 questions (Table 3) to record feedback on the following aspects:

- Indoor environmental conditions
- Daylight and ventilation
- Experience with the building materials and systems
- Affordability
- Maintenance and up-keep of the common areas
- Accessibility to the basic public facilities.

The responses for the various questions were a mix of objective answers, rating scale and multiple-choice questions.

Since the three selected climatic zones vary in their seasonal temperature variations, in order to access the residents' perception of the indoor environment in these naturally ventilated dwellings, the survey posed questions only for hot and cold seasons (summer and winter). This also allowed for a universally applicable questionnaire survey across all the selected locations. Even though the duration and intensity of these seasons vary for each climatic zone, there are transition periods where outdoor conditions are more comfortable. The survey therefore, focused on gaining feedback on a general perception during the hottest and coldest periods during the two seasons. For this the respondents were asked to rate their experience on a rating scale.

Table 3: Householder survey questionnaire

Ques. No.	Aspects accessed	Response								
	About the household									
1	Duration of occupancy	Survey was done for households that had been occupied for a minimum of 5-6 months.								
2	Number of residents in the house	Infants (< 3 years)		Children (< 18 years)		Adults (19-59 years)		Elderly (> 60 years)		-
3	Average number of hours spent at home on a daily basis	<4	4-6	6-8	10-12	12-14	14-16	16-18	18-20	>20
4	Percentage of monthly income spent on rent	Less than half		About half		More than half				
5	Monthly average electricity bill	Residents were asked to share a copy of their latest electricity bill if feasible.								
	Perceived indoor environment in summer & winter									
6	Indoor temperature	unsatisfactory		bearable		satisfactory		-		-
7	Air quality	stuffy		bearable		fresh		-		-

8	Air movement	draughty	still	well ventilated	-	-
9	Overall experience	unsatisfactory	bearable	satisfactory	-	-
10	Window shading during summer	None	Curtains/blanket /screen/ cloth/netting/ inside blinds	News paper	Cardboard	Plywood
11	Cooling strategies adopted during summer	Natural ventilation (opening windows at night)	Evaporation cooling (sprinkling water on the floor, using coolers)	Ceiling fan	Air conditioner	-
12	Adaptive strategy during winters	yes	no	-	-	-
13	Artificial lighting required during the day	yes	no	-	-	-
14	Dampness in the house	yes	no	-	-	-
15	Room in which there is dampness					
16	Causes of dampness	Leaking of pipes	Building material is not water resistant	Improper construction workmanship	Poor design	-
	Maintenance and repair					
17	Regular maintenance of common areas	yes	no			
18	Is payment made to the residential welfare association to cover the maintenance of common areas, service connections and the building itself?	yes	no			
19	What is your experience with respect to the building materials used? Any issues with options mentioned?	Satisfactory experience	Aesthetics/material finish	Nailability	Adding/changing electrical points	Inability to access pipe for plumbing repair works
20	Convenient access to essential facilities	yes	no	-	-	-
21	Travel time to work (minutes)	0-20	20-40	40 -60	60 min & above	-
22	Travel time to school (minutes)	0-20	20-40	40 -60	60 min & above	-
23	Mode of travel to work; hospitals and other essential services	Own vehicle	Access to public transport	Walking distance	Availability of conveyance is an issue	-
24	Mode of travel to school	Own vehicle	Access to public transport	Walking distance	School bus	No school going children in the house

With approximately 750 households to be surveyed across the five locations of social housing developments, the MaS-SHIP project team engaged with local architecture education institutions for assistance in conducting household surveys. Each of the local institutions selected 10 architecture students (3rd and 4th year students) to assist the MaS-SHIP team in conducting these surveys. As part of capacity building the students attended half a day orientation workshop, conducted by members of the MaS-SHIP team, post which another half of the day was spent on-site, assessing the progress made by the students in conducting the surveys. On an average each batch of 10 students took 4 days to complete the survey of a total of around 150 households at each site. Households were selected through random sampling and were generally suggestive of the availability of the members in the house as well as their eagerness to participate in the survey.

3.2 Photographic survey

The students conducting the survey also took pictures of the interiors of the dwellings and the surround areas (after seeking permission from the resident/s) to support the responses gathered from the householders.

3.3 Researcher observations

Apart from gathering information through the survey questionnaire and photographs, the students were also asked to provide their feedback regarding their experience with respect to conducting the survey and their observations about the development. This was done by completing two personal logs - one at the end of Day-1 of the survey and the second after completing the survey for that particular social housing development. The questions provided for the two personal logs are as below:

Personal log-Day 1

1. Were the home-owners responsive to the questions asked to them?
2. What worked or didn't work in your favour while conducting the surveys?
3. Do you feel the questions were relevant or irrelevant? Give reasons.
4. What was your overall experience in conducting the surveys?

Personal log report

1. What is your overall experience in conducting the surveys?
2. What is your understanding of social housing?
3. Is it different from other residential projects? Describe your observations.
4. Are there any concerns that you think need to be addressed with respect to social housing projects?
5. What are your recommendations for addressing these concerns?
6. Reflect on the building materials and systems used in the housing project and your assessment of these, against economic, social and environmental parameters.

The information derived from the student logs generally reaffirmed the findings from the questionnaire survey and also at places provided additional feedback regarding various aspects of any particular surveyed development. Some of the conclusions made in this report were also derived from the students' observations.

4. Insights from the householder survey

4.1 Perceived indoor conditions

This section highlights the findings from the residents' survey about their perception of the indoor environmental conditions (indoor temperature and air) in their homes during winter and summer. Table 4 shows the questions (as shown in Table 3) asked to the responders regrding their perception of the indoor environment, the response rating scale and the total number of responses received during the survey.

Table 4: Survey questions and householder responses for perceived indoor environment in summer and winter

Ques. no.	Aspects accessed	Response rating scale			No. of response (N)	
	Perceived indoor environment in Summer & Winter	**1**	**2**	**3**	Summer	Winter
6	Indoor temperature	unsatisfactory	bearable	satisfactory	148	146
7	Air quality	stuffy	bearable	fresh	148	146
8	Air movement	draughty	still	well ventilated	148	146
9	Overall experience	unsatisfactory	bearable	satisfactory	148	146

The survey results as shown in Figure 11 reveal that the number of residents' perceiving *indoor temperature* as *unsatisfactory* during summer is about three times of that during winters. The tolerance of *indoor temperatures* is observed to be higher in winters with more number of residents reporting feeling *satisfied*. A similar trend is seen in terms of the *indoor air quality* wherein 68 out of the 148 surveyed households, find their homes *stuffy* during summers, whereas in winters this number is reduced (25 out of 146), and more residents perceive *indoor air quality* to be *bearable* (Figure 12). In this study, *bearable air quality*, is assumed to correspond to a lesser stuffy house, an indoor condition which the residents have learnt to cope with.

Figure 11: Perceived indoor temperature

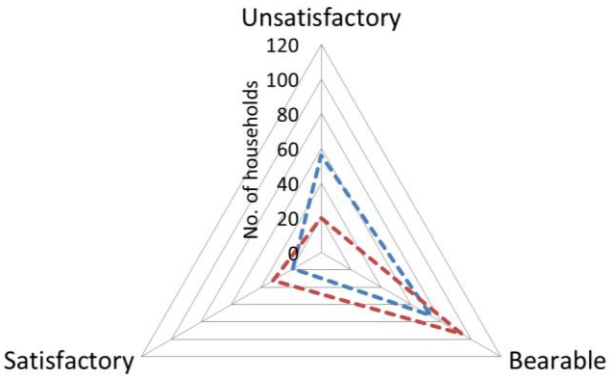
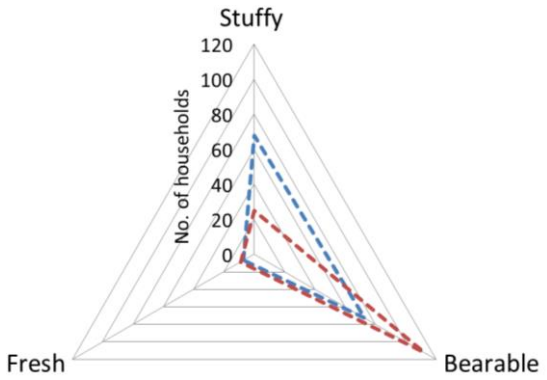


Figure 12: Perceived indoor air quality



winter summer

Despite the poor *indoor air quality*, on inquiring about the *indoor air movement* in their homes nearly 59% (87 out of 148) residents felt their homes were *well-ventilated* during summers. A substantial number of residents (30 out of 146) also complained of D*raughty dw (doors and windows)* during winters, whereas *still indoor air movement* was perceived by an equal number of residents during both summer and winter (Figure 13). Owing to the relatively better indoor conditions experienced during winters, nearly 21% (30 out of 146) of the residents perceive *satisfactory overall experience* inside their homes during winter, compared to the 12% (18 out of 148) *satisfied* residents during

summers. A higher percentage of residents (68%) perceived *overall experience* in winter to be *bearable* as compared to the 55% in summer (Figure 14).

Figure 13: Perceived indoor air movement

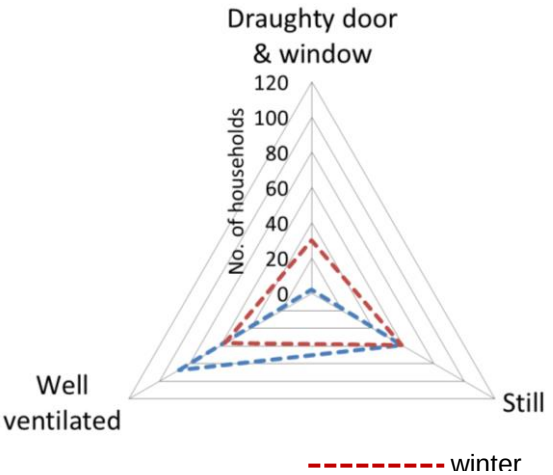
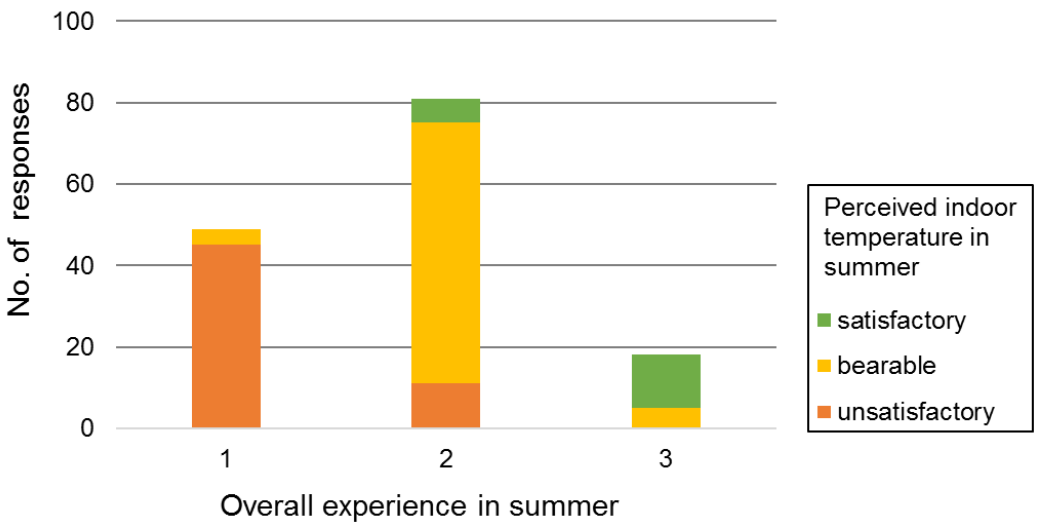


Figure 14: Overall experience

Deeper analysis of the survey responses for indoor environmental conditions was performed in order to access the influence of the perception of indoor temperature and air on the residents' overall experience during summer and winter. For this, the householders' responses for their perceived indoor temperature, air quality and air movement were cross related with their corresponding response for the overall experience during summer and winter.

The householders' responses for overall experience in summer were compared with their response for perceived indoor summer temperatures (as shown in graph in Figure 15 and cross-tabulation in Table 5).

Figure 15: Overall experience vs perceived indoor temperature in summer



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

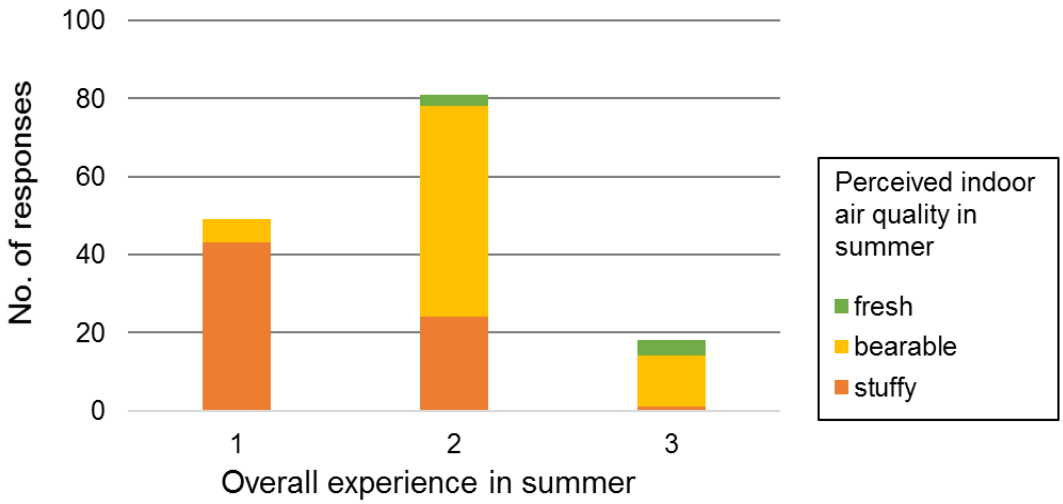
Table 5: Cross tabulation- overall experience vs perceived indoor temperature in summer

		Overall experience in summer			**Total**
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived Indoor temperature in summer	unsatisfactory	**45**	11	0	**56**
	bearable	4	**64**	5	**73**
	satisfactory	0	6	**13**	**19**
	Total	**49**	**81**	**18**	**148**

The survey revealed that an *unsatisfactory* perception of the indoor temperature had a direct impact on the residents' overall experience during summer and lead to an unsatisfactory overall experience. Of the 49 households reporting *unsatisfactory overall experience* nearly all (n: 45) the households perceived *indoor temperature* also to be *unsatisfactory* during summers (Figure 15). Similarly, *bearable* perception of the *indoor temperatures* lead to a *bearable overall experience*, as 81 households reported *overall experience* of the indoor environment as *bearable*, out of which majority (n: 64) households perceived indoor *temperature* also as *bearable.* Though 11 (out of 81) households perceived *indoor temperature as unsatisfactory*, but their overall experience remained *bearable*. Of the 18 households reporting satisfactory overall experience 13 households perceived *indoor temperature* also as *satisfactory*. The higher number of households perceiving indoor temperature as unsatisfactory or bearable, indicates the poor thermal performance of these dwellings which seems to have a substantial influence on the residents' overall experience of the indoor conditions during summer.

The householders' responses for *overall experience* in summer were compared with their response for perceived *indoor air quality* (as shown in graph in Figure 16 and cross-tabulation in Table 6).

Figure 16: Overall experience vs perceived indoor air quality in summer



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

Table 6: Cross tabulation - overall experience vs perceived indoor air quality in summer

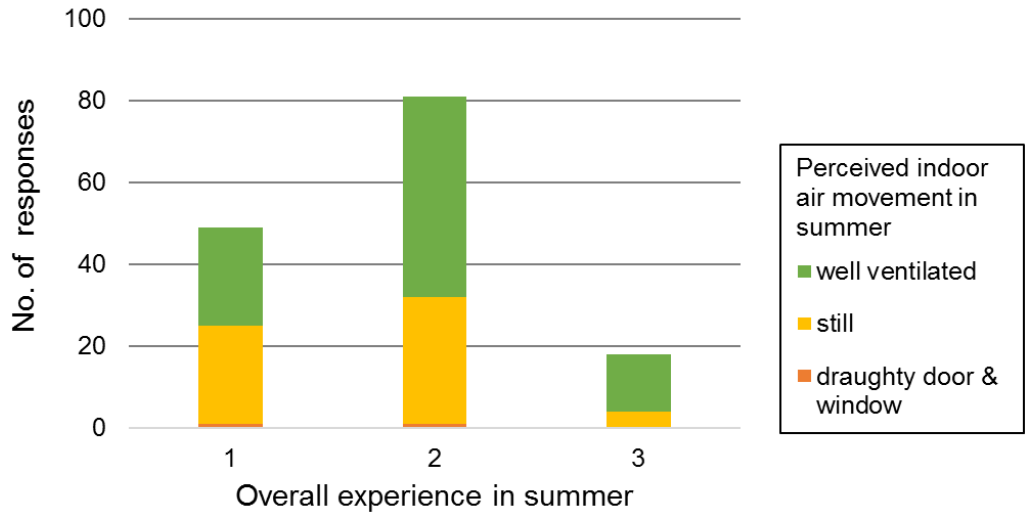
		Overall experience in summer			Total
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived indoor air quality in summer	stuffy	**43**	**24**	1	**68**
	bearable	6	**54**	**13**	**73**
	fresh	0	3	4	**7**
	Total	**49**	**81**	**18**	**148**

An unsatisfactory perception of indoor air quality too seemed to have a noteworthy effect on the residents overall experience during summer and lead to unsatisfactory overall experience. Of the 49 households reporting overall experience as unsatisfactory, 43 households perceived indoor air as stuffy. Similarly, a bearable perception of indoor air quality lead to an overall bearable experience and is indicated by the fact that of the 81 households with bearable overall experience 54 perceived indoor air quality also as bearable during summer. Interestingly for households with *satisfactory overall experience* during summer (n: 18) the number of households with perceived *indoor air quality* as *bearable* remained highest (n: 13), indicating towards the poor air quality of the interiors during summer. During summers residents in most of these dwellings either perceived

indoor air quality to be *stuffy* or *bearable* which to an extent influences their *overall experience* of the indoor environment.

The householders' responses for *overall experience* in summer were compared with their response for perceived *indoor air movement* (as shown in graph in Figure 17 and cross-tabulation in Table 7).

Figure 17: Overall experience vs perceived indoor air movement in summer



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

Table 7: Cross tabulation- overall experience vs perceived indoor air movement in summer

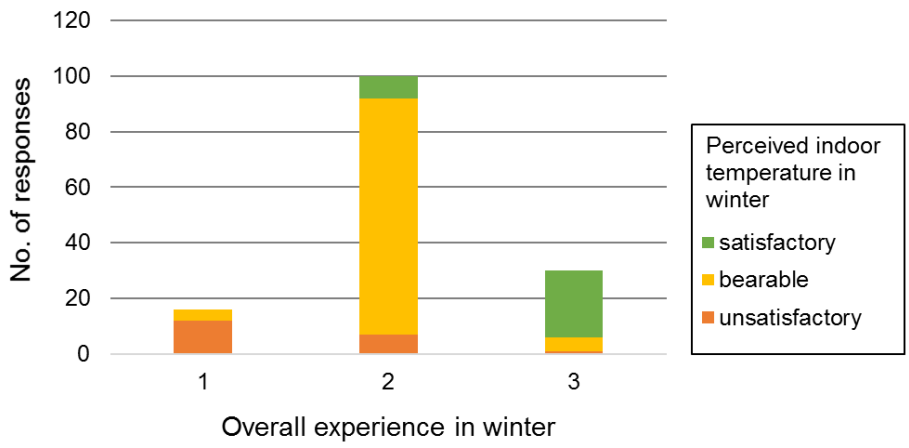
		Overall experience in summer			**Total**
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived Indoor air movement in summer	Draughty door & window	1	1	0	**2**
	still	**24**	**31**	4	**59**
	well ventilated	**24**	**49**	14	**87**
	Total	**49**	**81**	**18**	**148**

The perception of *indoor air movement* seemed to have a slightly mixed effect on the residents' *overall experience* of the indoor environment during summer. It was observed that of the 49 households reporting *unsatisfactory overall experience* equal number of households (n: 24) perceived *indoor air movement* as *still* and *well-ventilated*. Similarly, for the 81 households with *bearable overall experience*, though the number of residents perceiving *well-ventilated* indoors was highest (n: 49), a substantial number of households also perceived indoor air as *still*. Well ventilated indoors however seemed to result in a *satisfactory overall experience* for some householders (14 out of 18) during summer. Given that these dwelling are naturally ventilated, air movement plays a significant role in determining residents' comfort levels even in summers. Though the external temperatures in Delhi are high during the day in summers, this indicates the potential of using night time ventilation for cooling these types of dwellings.

A similar comparison of the various factors affecting the residents' overall experience of the indoor conditions was done for the survey responses for winter months.

The householders' responses for *overall experience* in winter were compared with their response for perceived *indoor temperature* (as shown in graph in Figure 18 and cross-tabulation in Table 8).

Figure 18: Overall experience vs perceived indoor temperature during winter



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

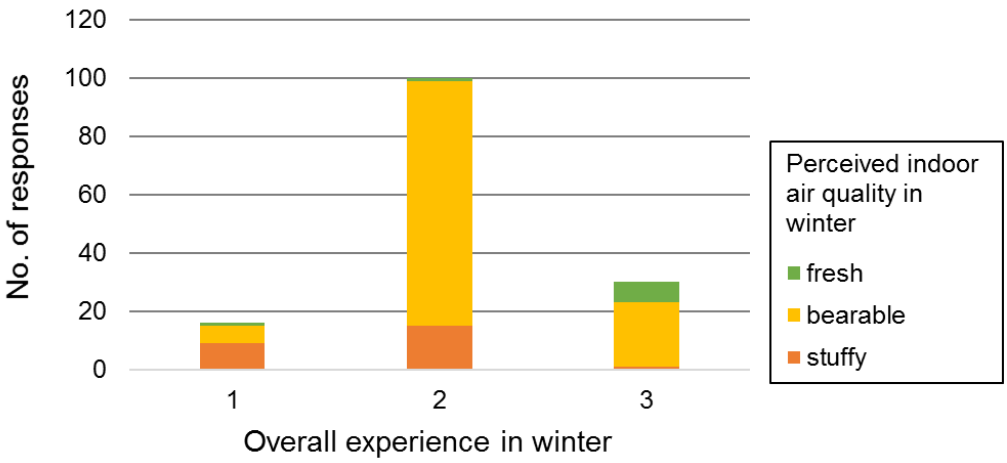
Table 8: Cross-tabulation- overall experience vs perceived indoor temperature in winter

		Overall experience in winter			**Total**
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived Indoor temperature in winter	unsatisfactory	**12**	7	1	**20**
	bearable	4	**85**	5	**94**
	satisfactory	0	8	**24**	**32**
	Total	**16**	**100**	**30**	**146**

Similar to summer, during winter too the perception of *indoor temperature* seems to have a significant impact on the householders *overall experience* of the indoor environment. Of the 100 households reporting *overall experience* as *bearable* during winter, majority (n: 85) households perceived *indoor temperature* also to be *bearable* (Table 8). Similarly, 30 households reported *overall satisfactory experience* during winter, out of which 24 households perceived *indoor temperature* also to be *satisfactory*. A higher number of households with both *bearable* and *satisfactory* experience indicate greater capacity of the residents to adapt to their surroundings during winters and its direct impact on the residents' overall experience of the indoor environment.

The householders' responses for *overall experience* in winter were compared with their response for perceived *indoor air quality* (as shown in graph in Figure 19 and cross-tabulation in Table 9).

Figure 19: Overall experience vs perceived indoor air quality in winter



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

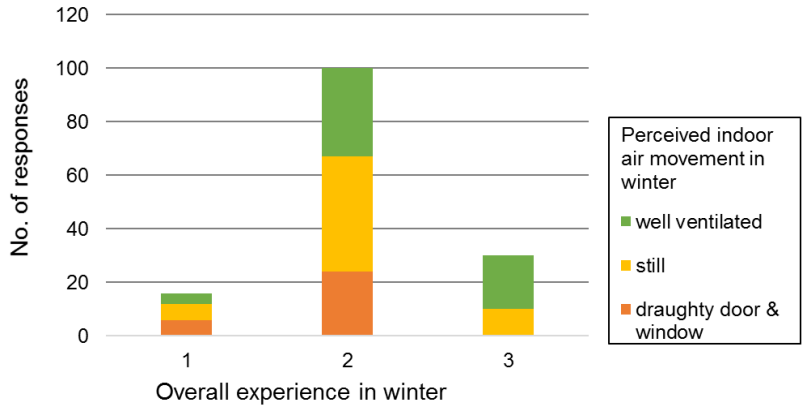
Table 9: Cross tabulation- overall experience vs perceived indoor air quality in winter

		Overall experience in winter			Total
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived Indoor air quality in winter	stuffy	9	15	1	**25**
	bearable	6	**84**	**22**	**112**
	fresh	1	1	7	**9**
	Total	**16**	**100**	**30**	**146**

The survey revealed that though as compared to summer, *indoor air quality* was perceived to be *bearable* by more number of residents in winter; this did not seem to have any significant effect on their *overall experience* of the indoor environment. Of the 100 households reporting overall bearable experience majority households (n: 84) perceived *indoor air quality* also as *bearable.* Interestingly number of households perceiving *indoor air quality* was also found to be highest (n: 22) for the 30 households reporting *satisfactory overall experience* during winters. Overall of the 146 surveyed households, nearly similar number of households perceived both *indoor air quality* and *overall*. Overall, the number of households perceiving *indoor air quality as stuffy* was nearly one third of that during summer. Better indoor air quality in winters can be attributed the lower levels of external temperature and humidity and a reduced need for air change during winters.

The householders' responses for *overall experience* in winter were compared with their response for perceived *indoor air movement* (as shown in graph in Figure 20 and cross-tabulation in Table 10).

Figure 20: Overall experience vs perceived indoor air movement in winter



Overall experience: 1= Unsatisfactory; 2= Bearable; 3= Satisfactory

Table 10: Cross tabulation- overall experience vs perceived indoor air movement in winter

		Overall experience in winter			Total
		1=unsatisfactory	2=bearable	3=satisfactory	
Perceived indoor air movement in winter	Draughty door & window	6	24	0	**30**
	still	6	**43**	**10**	**59**
	well ventilated	4	**33**	**20**	**57**
	Total	**16**	**100**	**30**	**146**

Unlike summer, in winter of the 100 households with *bearable overall experience*, the number of households with *still indoor air* was found to be highest (n: 43). Indicating residents' preference of still indoor air during winter. Of the 30 households with *satisfactory overall experience* during winters two third (n: 20) households perceived their dwellings to be *well-ventilated*. *Draughty door and windows* were perceived by 30 households in winters, which majorly lead to their overall bearable experience. Still indoor air seemed to make the overall indoor environmental conditions more bearable for majority of the residents; while some others also preferred well-ventilated homes even during winters.

The above analysis of the survey data is based on correlating the householders' response of their overall experience of the indoor environment during summer and winter with their corresponding response for the perceived indoor temperature and air.

In the composite climate of Delhi, which is characterised by high temperatures in summers and cold in winters; the residents of Bawana housing mostly found the indoor environmental conditions in these dwellings as *bearable* during both summer and winter. The results indicate ventilation/air movement as a seemingly significant factor influencing the occupants' overall experience throughout the year and that well ventilated homes are preferred by the occupants during both summer and winter. In summers, however, a majority of well-ventilated households reported only bearable overall experience, understandably because these dwellings are naturally ventilated and due to high external temperatures in Delhi during summers, ventilation during the day may not always have cooling effect. Similar observations were made using the survey responses for the winter months. Though the number of households with *overall experience* as *satisfactory* is highest in winters when they perceive their homes to be *well ventilated*, for any given perception of *indoor air movement*, the *overall experience* of the occupants' remains mostly bearable during winters; indicating a relatively weak impact of air movement on indoor comfort during winter.

In winters, the perception of both indoor temperature and air quality remains bearable for majority of the households and this corresponds with their overall bearable experience. A significantly lower number of occupants feeling unsatisfied with the indoor temperature and air quality in winters as compared to that in summers, indicates greater adaptability of the occupants during winters and also the need for adopting better passive cooling strategies in order to improve indoor comfort, during summers.

Further, statistical correlation methods were also applied in order to understand the correlation between the factors influencing residents' perception of indoor conditions. Spearman's correlation coefficient (r_s), also called Spearman's rho, is used to establish the correlation between the rankings of two variables. The value of r_s ranges from -1 to +1, the closer r_s is to ±1 the stronger the monotonic relation between the two variables. Kendall's Tau-b (τ_b) correlation coefficient, also considered as an alternate to the Spearman's correlation is a nonparametric measure of the strength and direction of association that exists between two ordinal variables. Both statistical tests when applied to the householder survey responses for indoor environmental conditions show similar results. The Spearman's correlation coefficient (r_s[1]) values of 0.803 and 0.712 (Table 11) for *overall experience* vs perceived *indoor temperatures* in summer and winter respectively, reveal *indoor temperatures* as a noteworthy factor in influencing the householders' perception of the overall indoor environment during both summer and winter. Whereas the r_s values of overall experience vs perceived *indoor air quality* shows strong correlation between the two variables in summer, but shows weak correlation in winter. Correlation coefficient values for *overall experience vs* perceived *indoor air movement* indicate weak correlation between the two variables, during both summer and winter.

Table 11: Spearman's correlation coefficient

		Spearman's correlation coefficient
Overall experience in summer vs	Indoor temperature	0.803
	Air quality	0.616
	Air movement	0.175
Overall experience in winter vs	Indoor temperature	0.712
	Air quality	0.406
	Air movement	0.322

[1] Guide to determine the strength of correlation for absolute value of r_s
00-0.19 "very weak"; 0.20-.39 "weak"; 0.40-0.59 "moderate"; 0.60-0.79 "strong"; 0.80-1.0 "very strong"

Through multiple statistical analyses, a greater correlation between the perceived indoor temperature and overall experience of the indoor environment during both winter and summers is observed. While this may differ in reality which will require a next level analysis of quantified indoor temperatures vs the comfort temperature, this could also be attributed to the design of the questionnaire survey. Considering the fact that the occupants were asked of their perception of indoor temperature, air quality, and air movement, temperature is often a more palpable parameter for the people to realise as a factor of comfort or discomfort.

4.2 Comfort strategies adopted during summer and winter

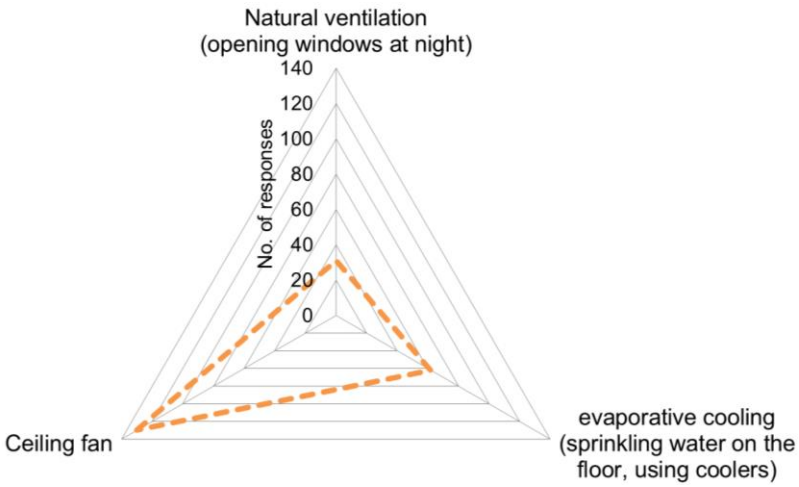
The researchers (students) also inquired from the residents about the adaptive measures used to improve indoor thermal comfort during summer and winter. Table 12 shows the survey questions asked to the responders (as shown in Table 3) their responses and the number of responses received, regarding the comfort strategies adopted during summer and winter. The householders were allowed to choose more than one of the options as their response.

Table 12: Survey questions and householder responses for comfort strategies adopted during summer and winter

Ques. no.	Aspects accessed	Response					
			N		N		N
11	**Cooling strategy adopted during summers**	Natural ventilation (opening windows at night)	31	Evaporation cooling (sprinkling water on the floor, using coolers)	62	Ceiling fan	130
12	**Adaptive strategy during winters**	Blankets & shawls	4	Bon fire	24	Electric heater	11

The survey showed the use of celling fans as a basic and most common measure adopted by the residents of Bawana housing to provide cooling in the hot Delhi summers. Out of the 130 residents using ceiling fans about 30 also reported opening windows to allow for night time ventilation cooling. A substantial number of households could afford desert cooler which enhanced the indoor temperature through evaporative cooling. Sprinkling water on the floor also emerged as a way that the residents resorted to in order to reduce indoor temperature through evaporative cooling (Figure 21).

Figure 21: Cooling strategies adopted during summer



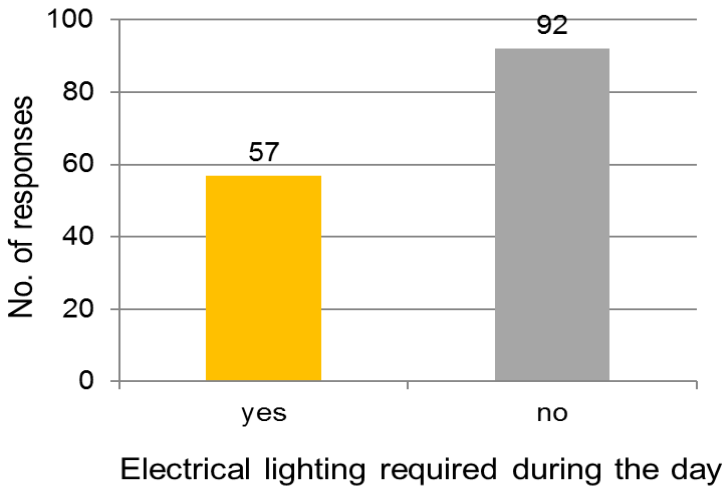
Despite the external temperatures dropping as low as 4 to 10 deg. C (Bureau of Energy Efficiency, 2011) during winters, maximum number of households reported using no extra measure to adapt to

the reduced external temperatures. Some of the surveyed households also reported using fire (in the form of bon-fire outside the house). Use of electric heaters was seen in negligible number of households, presumably due to the relatively high electricity bills associated with their use. Also as seen in section 4.1, lesser number of households experienced overall bearable indoor conditions because a higher number experience satisfactory conditions in winters, it can be indicative of the relatively better thermal performance of these dwellings and/or the higher adaptive capacity of the residents during winter.

4.3 Daylighting

The quality of indoor lighting was accessed by asking the residents if they needed to use artificial/electrical lighting during the day (question 13 in Table 3). Nearly one third (57 out of 149) of the surveyed households reported that they needed to use electrical lighting during the day. Though the survey did not prompt the residents to provide reasons for their response, a few observations made by the researchers reveal either the absence of residents at home during the day; or availability of adequate diffused light to carry out their tasks. It was also observed that houses on the upper floors generally do not require electrical lighting during the day.

Figure 22: Electrical lighting requirement during the day



4.4 Window shading during summer

Table 13 shows the question (as shown in Table 3) asked to the responders, their responses and the number of responses received about additional measures adopted for window shading during summers. During the survey a majority number of residents were found using either curtains or screens to shade their windows during summer. A few houses had their windows covered with either newspapers or cardboard. Two householders closed their windows completely by plywood due to security or privacy issues.

Table 13: Survey question and householder responses for additional window shading used in summer

Ques. no.	Aspects accessed	No. of response									
			N		N		N		N		N
10	**Window shading during summer**	None	23	Curtains/screen/ cloth/netting/ inside blinds	116	News paper	1	Card-board	7	Plywood	2

4.5 Dampness

The study also focused on visually analysing the quality of construction and building materials used and sought the residents' perception of it through the survey questionnaire. During the interview the researchers inquired about the presence of dampness in that particular dwelling, its specific location and then prompted the respondents to choose one or multiple response from the given options, as to what they perceived the cause for it. Table 14 shows the survey questions (as shown in Table 3) and the householders responses in this regard.

Table 14: Survey questions and householder responses regarding presence of dampness in the dwellings.

Ques. no.	Aspects accessed	Response				No. of responses
14	Dampness	yes		no		149
16	Causes of dampness	Leaking of pipes	Building material is not water resistant	Improper construction workmanship	Poor design	149

The poor quality of constriction and materials was evident in the presence of dampness inside many surveyed dwellings. Nearly 58% (86 out of the 149) of the surveyed households reported presence of dampness in their dwelling (Figure 23). Majority of these householders reported dampness on the kitchen and/or toilet walls. Nearly equal number of these households perceived *leaking of pipes (poor plumbing)* and/or *building materials not being water resistant* as a cause of dampness. Some of the households also attributed dampness to *improper construction workmanship*, while a very few of them attributed it to the *poor design* of the dwelling (Figure 24).

Figure 23: Presence of dampness inside the dwelling

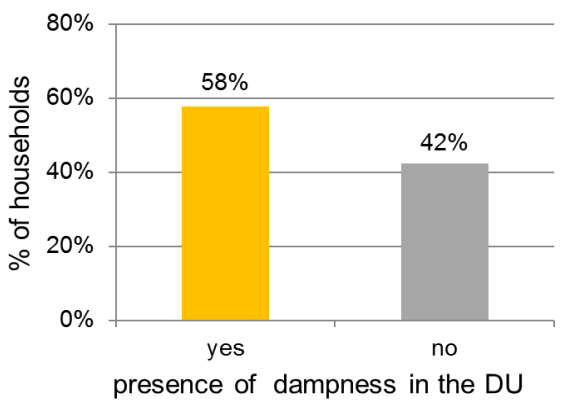
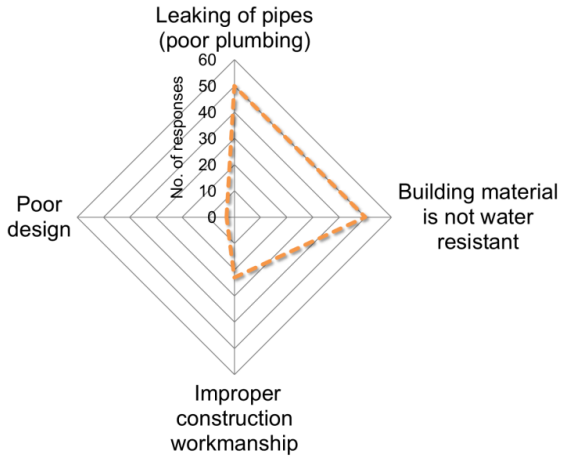


Figure 24: Perceived causes of dampness



4.6 Maintenance and repair

The researchers (students) also inquired from the householders about the maintenance and repair mechanisms in place for the development and if they paid any charges for maintaining the common areas of the building and its surroundings. Table 15 shows the survey questions asked in this regard and the number of responses received.

Table 15: Survey questions and householder responses regarding maintenance and repair of the development

Ques. No.	Maintenance and repair	Response			
			N		N
17	Is the maintenance of the common areas and building regularly done?	yes	10	no	139
18	Do you pay into a resident's welfare association to cover maintenance and repair costs for common areas and the building?	yes	10	no	139

Almost all the surveyed households expressed disappointment regarding the up-keep and maintenance of the common areas. Out of the 149 surveyed households, 139 reported absence of any maintenance system for the housing development. The open courtyards meant to promote community interaction were seen filled with garbage and water logging was a common sight along the streets, due to poorly designed and maintained open drains. A few residents made efforts to clean their immediate surroundings, but the development at large lacks cleanliness and hygiene (Figure 25 & 26).

Figure 25: Street view of Bawana housing

Figure 26: Street view of Bawana housing

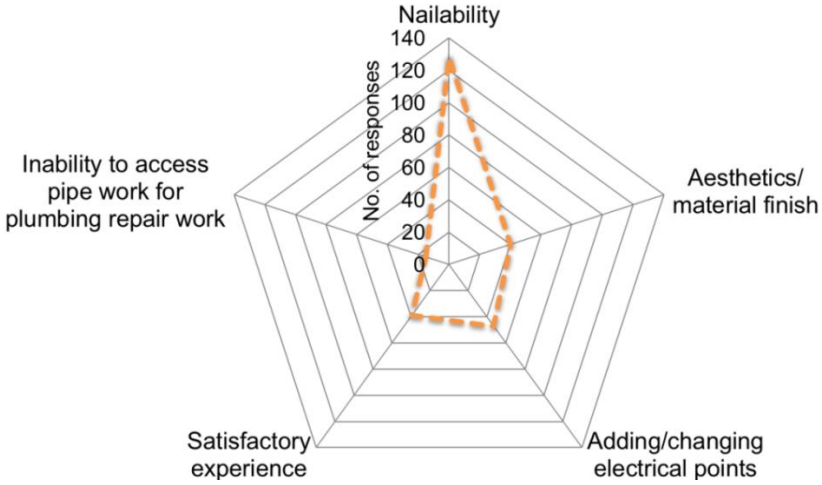
The householder survey questionnaire also focused on gathering feedback from the residents regarding their experience with the building materials used in the dwellings. Table 16 shows the survey question and responses of the householders' experience with the building materials of the dwellings. For this survey question the householders were allowed to choose more than one response.

Table 16: Survey question and householder responses regarding experience with the building materials

Ques. No.	Aspects accessed	Response					No. of response (N)
19	What is your experience with respect to the building materials used? Any issues with options mentioned?	Satisfactory experience	Aesthetics/ material finish	Nailability	Adding/changing electrical points	Inability to access pipe for plumbing repair works	149

Though the building materials used may have proven to be economical and sustainable in some sense, the experience of the residents living in these homes seems largely that of dissatisfaction. The flexibility of being able to adapt their dwelling as per one's own day to day needs and aspirations is an elementary need of every human being. The survey revealed 'Nail-ability 'i.e. the suitability [of a wall] for being nailed, as a major concern among majority of the residents. The current choice of materials and the quality of construction of these houses, does not allow the residents to make basic alterations to the interiors, like hanging a piece of art or a shelf to the walls, or adding or changing an electrical point. People also expressed their concern regarding the access to the plumbing pipes which poses limitations in carrying out any repair works. Some of the residents also voiced their opinion on the aesthetics of the buildings, which of course is subjective and pertains to the architectural design and/ or external/internal finishes of the building (Figure 27**Error! Reference source not found.**).

Figure 27: Householders experience with the building materials used



4.7 Location

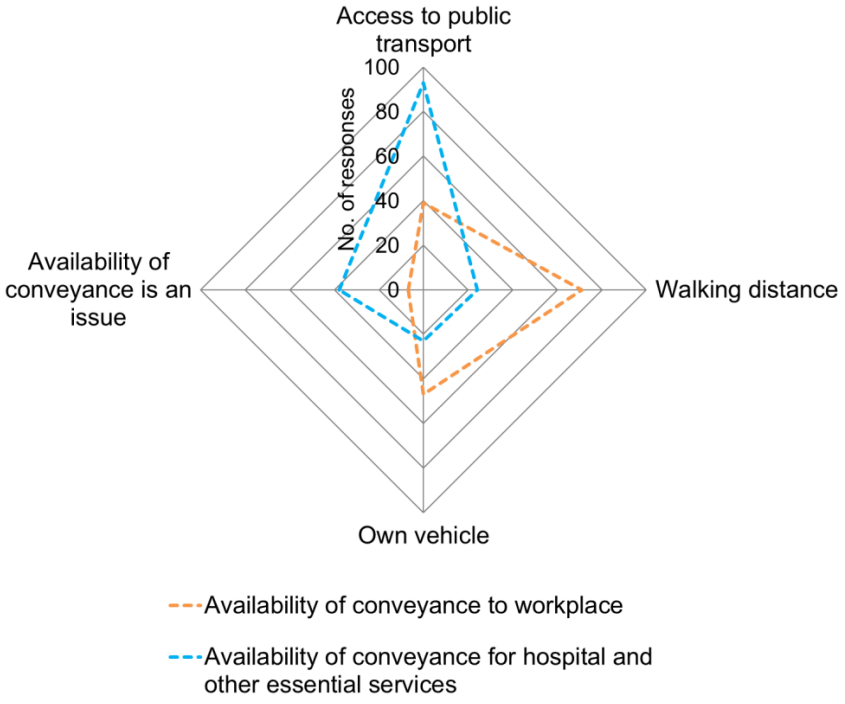
The survey questionnaire also covered aspects related to the location of the development. Table 17 shows the survey questions (as shown in Table 3) asked to the responders and their responses regarding accessibility to basic facilities. The Bawana housing development is located on the outskirts of Delhi, approximately 30 km away from the city centre. During the survey it was observed that for most residents (95 out of 149) the place of work is up to 20 minutes' walk from the development.

Table 17: Survey questions and householder responses regarding aspects related to the location of the development.

Ques. No.	Aspects accessed	Response					No. Of response (N)
20	Convenient access to essential facilities	yes			no		149
21	Travel time to work (minutes)	0-20	20-40	40 -60	60 min & above	-	149
22	Travel time to school (minutes)	0-20	20-40	40 -60	60 min & above	-	90
23	Mode of travel to work; hospitals and other essential services	Own vehicle	Access to public transport	Walking distance	Availability of conveyance is an issue	-	149
24	Mode of travel to school	Own vehicle	Access to public transport	Walking distance	School bus	No school going children in the house	90

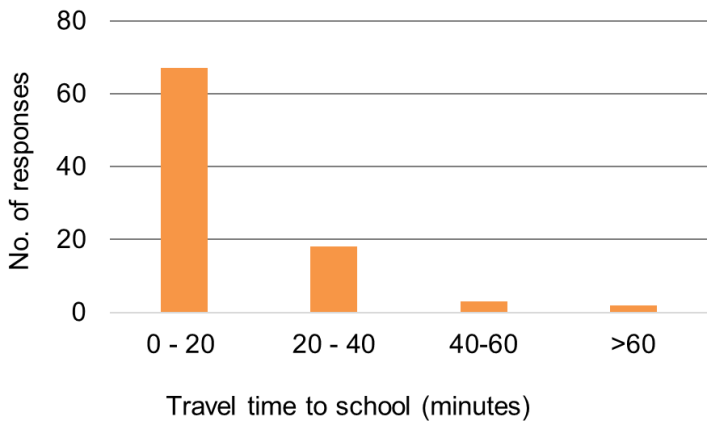
A substantial number of people also have vehicles of their own to commute to work and other places. Out of the 149 surveys gathered, 39 households also reported adequate access to public transport (Figure 28). However, a general impression was that of dissatisfaction among the residents regarding the unavailability of proper job opportunities in the neighbourhood. Maximum number of residents of the Bawana housing reported having access to public transport for traveling to hospitals and other places of utility. However, they also expressed concern about the less numbers and availability during night.

Figure 28: Mode of travel



Out of the 149 surveyed households, 90 had school going children. For a majority of the children the schools are at walking distance and it takes about 0-20 minutes to travel to school. Few children take longer time to reach to their respective schools (Figure 29). The feedback from the residents reveals that connectivity to the basic services is available and that they have also adopted their day to day dynamics to adjust to their surroundings. Safety, however, seems to be a concern for children and women in the area.

Figure 29: Travel time to school (minutes)

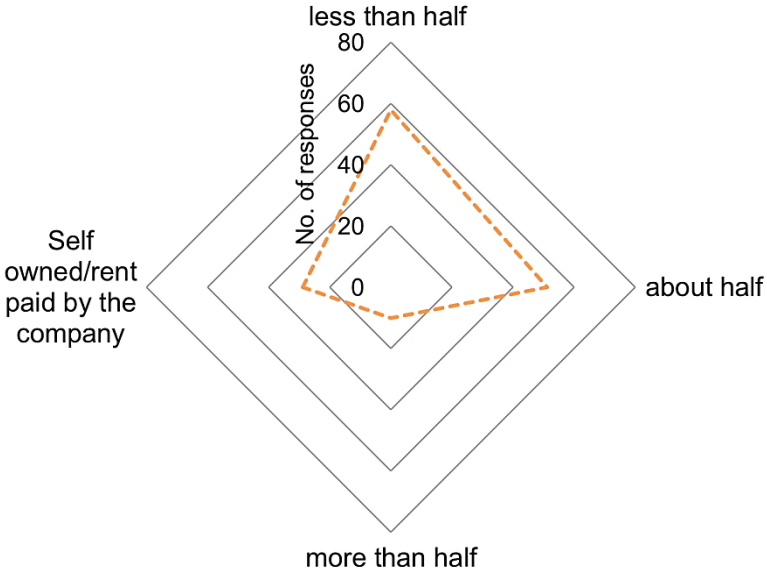


4.8 Affordability

The survey questionnaire also covered the aspect of affordability by inquiring from the residents about the household expenditure on monthly rent and electricity bills (question no. 4 and 5, Table 3). At the time of the survey, it was observed that most of the original owners of these dwellings had moved to a different location and rented out their houses in this development. Out of the 149 surveyed households, 119 houses were occupied on rent. A majority of them paid monthly rent less than half of their monthly income. An almost similar number of households also reported spending half of their income in house rent every month (Figure 31). Majority of the surveyed households paid monthly

electricity bill between 450 to 600 INR, while a substantial number of residents also reported paying less than 450 INR for electricity per month. A few households paid as high as 1050 INR or more for electricity every month

Figure 30: Proportion of monthly income spent on rent



5. Conclusions

- The Bawana housing development was constructed with the intention to rehabilitate the industry workers and people from EWS in a settlement with better living conditions. Although the building materials used in the project were low cost and environment friendly, the householder survey revealed that indoor comfort was perceived to be (just) bearable during summer and winter. Only 12% of respondents rated their indoor conditions as 'satisfactory' in summer, whereas nearly the same proportion (11%) rated it as 'unsatisfactory' in the winter. This indicated the inability of the dwelling units to provide comfortable indoor environment in the summer (in absence of air-conditioning). However in winter, higher levels of adaptation occurs wherein residents resort to warm clothing and blankets, along with a reduced heat loss due to small size/exposure of the dwelling units. Air inside dwellings was perceived to be still by one-third of residents, though still air was desirable in winters.
- Statistical analyses of the survey data showed correlation between overall experience and perceived indoor temperatures in summer and winter respectively, reveal indoor temperatures as a noteworthy factor in influencing the householders' perception of the overall indoor environment during both summer and winter
- The survey also helped to reveal critical factors that determine the acceptability of building materials from the householders' perspective. The factory finished exposed brick work used for the wall may have helped to reduce the initial construction cost, but nailability of the walls emerged as a major concern for the residents, since the wall materials did not allow residents the flexibility of making basic alterations to the interiors.
- It was also realised that poor quality of plumbing and workmanship was widespread in the development. Presence of dampness was found in many dwellings, with residents expressing dissatisfaction with the inaccessibility of the pipe work and poor water proofing. It is vital that construction quality is kept high in such projects to reduce maintenance costs in the future.
- There appears to be a lack of maintenance regime for the upkeep of the common areas. The survey revealed that unoccupied dwelling units had become dumping yards with garbage spill-over in the streets. An institutional system for regular maintenance must be put in place to ensure the health of the residents'.
- At the time of the survey, about 80% of the surveyed households were found to have tenants. The residents also expressed their dissatisfaction about the availability of job opportunities within accessible distances from the development. It was evident that due to the location of the development, most of the residents were forced to relocate back in order to retain their jobs in the city.