9. Green vs. concrete

The future of low-income mass housing amid climate-change uncertainties in India

Aboli Mangire

Introduction: The socio-ecological challenges of Indian housing missions

Low-income mass housing missions in India aim to eradicate slums and build new standardized dwelling units for the urban poor. Among India's most widely active missions over the last 20 years have been the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), Slum Rehabilitation Housing (SRH), and Pradhan Mantri Awas Yojana-Urban (PMAY-U) programmes. Founded on the 'slum-free cities' vision, these missions have been delivering structurally improved dwelling units in Indian cities. The JNNURM is recognized as the mission that initially delivered a number of slum improvement projects, but these eventually dwindled in number. Under the SRH programme, despite having been provided new dwelling units in cities such as Mumbai, inhabitants tended to reject the SRH housing estates and retreat to slums. The most recent of the missions, the PMAY-U, is learning from its predecessors while moving ahead with the vision of *housing for all by 2022* (MoHUPA, 2015). Even though it did not meet its goal of building 20 million homes by 2022, the PMAY-U mission has delivered housing with unprecedented speed: Between 2015 and 2023, 7.5 million homes were supplied to the urban poor of India. Yet, a number of social challenges still persist. Researchers worldwide have criticized mass housing projects for acting as planned environments that reproduce or reshape poverty; they are thus sceptical of the resettlement of slum dwellers into such estates (Doshi, 2013; Bhan, 2017). I refer to this debate to gain a critical perspective on the Indian housing ministry's vision, which can be interpreted as poverty-alleviating but may not truly be so. Therefore, I argue that the actual policy manifestations must be questioned and disentangled from the evidence available for public use.

What is more, Indian policy makers and inhabitants have been faced, during the same time frame, with the intensifying phenomenon of rising temperatures and heatwaves. India is a country largely dominated by areas with a high cooling demand. Above 96% of its population and new construction are located in the four climatic zones that typically require space cooling.[1] The challenge of climate change is becoming strongly visible in the steady rise of space cooling demand due to factors such as a growing population in a tropical climate as well as rising aspirational needs fuelled by sustained economic growth.[2] Added to this, an exacerbating backdrop is provided by the urban heat island phenomenon, that is, increased urban temperatures resulting from a number of key causes, including the density of cities, an increase in hard and heat-absorbing surfaces, and a reduction in natural vegetation (Mohajerani et al., 2017). Heatwaves, urban heat islands, and a high demand for space cooling represent a worsening ecological balance in the face of urbanization and climate change. Low-income populations in this scenario are especially vulnerable and will be faced with additional unforeseeable cooling costs. Thus, Indian mass housing missions, although they are rapidly catering to the slum-free cities vision, face socio-ecological challenges that impede long-term sustainability.

Owing to specific features of the Indian metropolis – its speed of urbanization, limited land for construction, and housing missions such as PMAY-U – the low-income building typology can be seen as changing over the last decade from low-rise slums, chawls, and group housing to denser mid-rise apartment blocks. Climate-induced challenges have drawn attention to creating affordable and energy-efficient architecture for mass housing, specifically through passive cooling design[3] and green spaces. Historically, architects in the Indian subcontinent have relied on diverse building elements and techniques for

1 *Energy Conservation Building Code for Residential Buildings* (BEE, 2018). This building code document is published by the Bureau of Energy Efficiency (BEE), within the Ministry of Power.

2 *India Cooling Action Plan: Operationalizing Space Cooling Recommendations*. This 2019 policy document, published by the Ministry of Environment, Forest and Climate Change (MEFCC, 2019), aims to create a macro-level policy tool to manage India's growth in the need for space cooling.

3 Passive cooling design is a branch of passive solar design defined as low-energy and low-cost, with techniques to reduce dependency on mechanical ventilation, used to prevent or modulate heat gains and to improve thermal comfort. It is characterized

transferring heat and preventing overheating (Kamal, 2012). The typology change has retained a few traditional overheating prevention techniques, including solar shading, cantilevers, and light shafts. On the other hand, heat-transfer techniques such as courtyards, open green spaces, and shade trees are notably reduced in number in the new typology. Researchers have argued that these ecologically conscious heat-transfer techniques positively catered to the social and cultural needs of inhabitants (Kamal, 2012; Gupta and Joshi, 2021). Some of these arguments refer to examples such as courtyards being used as kitchen facilities and for recreation, open green spaces hosting multigenerational leisure activities, and tree platforms signifying a communal assembly point. Careful attention to these dynamics is thus necessary to ensure that the social, cultural, and ecological impact of diminishing courtyards, open green spaces, and large shade trees is adequately taken into consideration to suit the new typology as well as inhabitants' daily lives.

Even though Indian housing missions advocate for integrating passive cooling design in low-income mass housing buildings, there are hurdles along the way toward implementation. The problem is not merely architectural or of urban design, but rather one that entails an entanglement of the housing missions' visions, inhabitants' responses to the actual built outcomes, and the increasing energy demands triggering indeterminable effects. The problematization thus involves two levels. First, there is the uncertainty emerging from a mismatch between a housing mission's vision and inhabitants' acceptance of the newly built housing. Second, the newly built housing must meet newer and future climate necessities for which the existing measures will not be adequate. To address this problem of implementing passive cooling design, I draw on methodological elements from environment-behaviour studies (E-B studies) to conduct qualitative spatial research (Creswell, 2007). In particular, I examine the practices and tools used by built environment professionals as a contingency to cope with current as well as potential future challenges. This includes providing formal housing that not only resists the growth of slums (current challenge) but also meets the demand for space cooling (future challenge), and how the in-between mismatch is dealt with or not dealt with. The socio-spatial approach of environment-behaviour theories allows for a critical analysis of data drawn from social and spatial disciplines on three

by saving energy and associated costs and hence improving building energy efficiency (Asimakopoulos and Santamouris, 2013).

timescales: the vision and plans in the past, material form and its acceptance in the present, and the vision and planning for the future.

The mass housing case study selected for this research is located in the Pune metropolitan region in India. Pune is the ninth largest city by population in the country and second largest (Mumbai is first) in the federal state of Maharashtra. Once known as a *green haven*, the city has witnessed a phenomenal rise in its population due to expanding IT hubs, industrial growth, and nationally renowned universities and other educational institutions. Urban expansion has led to deforestation, loss of green cover (Kantakumar et al., 2016), and rising levels of air pollution. I carried out qualitative spatial research in the years 2023 and 2024 on housing buildings constructed in the year 2010. This case study's contribution is intended to provide empirical evidence of opportunities and barriers in the daily lives of inhabitants, as studied closely in relation to the form and materiality of housing. A further intention is to contribute to the growing knowledge base on the integration of passive cooling designs in standardized housing blocks. It is important to note that in this research the resettlement aspect of low-income housing, although a crucial aspect, is not under investigation. Therefore, the resulting effects of resettlement, such as community-loss, displacement, or loss of employment (Marcuse,1985; Cernea, 1995; Slater, 2009) are deliberately left out of the scope of this research. On the other hand, this research aligns itself within a debate in urban design that primarily argues that the densification of mass housing forms has had a negative impact on liveability, reducing inhabitants' mental, physical, and social well-being (Newman, 1973; Coleman, 1985; Evans et al., 2000; Dempsey et al., 2011; Jana et al., 2022).

The structure of this chapter is laid out as follows. The next section begins by detailing the policy, built-environment, and social contexts of Indian metropolitan cities. The subsequent section highlights the current state of research in environment-behaviour studies (E-B studies), and post-occupancy evaluation (POE) research then details specific research gaps. The fourth section presents the case study and research methods. Findings in the subsequent section are structured into three dimensions, namely, technical, functional, and behavioural. The final section discusses the lessons from this case to inform the broader discussion of contingencies in urban future-making, before a brief concluding section.

Low-income mass housing and climate-change challenges: The Indian context

India's Ministry of Housing and Urban Poverty Alleviation (MoHUPA), hereafter referred to as the Indian housing ministry, or housing ministry, initiated low-income mass housing programmes through a central funding support structure. The leading national objectives include fulfilling the dream of every person to own their own home, as well as completing the massive construction of dwelling units by 2022. For the current housing mission, PMAY-U, the housing ministry is approaching these objectives with three strategies – listing best practices with model projects, standardization of construction, and planning norms (MoHUPA, n.d.). The first of the three strategies that guide the PMAY-U mission is set out in a housing ministry compendium titled *Best Practices: Habitat Planning and Design for the Urban Poor*. It contains a list of 15 model projects from previous housing missions (JNNURM, RAY, BSUP). Out of a total of 15 listed model projects, 9 are related to the relocation and complete transformation of slums into mass housing, while 6 projects are about the in-situ improvement of original housing on its original land. In this compendium, the housing ministry uses the term *slum* abundantly in relation to key words and phrases such as *rehabilitation, low standard of living, clearing off slums, slum-free city, relocation to private land, and key role of private sector* (MoHUPA, n.d.). The *Best Practices* compendium serves as published evidence of how the housing ministry envisions the PMAY-U mission as a radical shift from incremental, low-scale, in-situ slum improvement projects towards clearing the slums, relocating residents, and constructing new mass housing on new land.

A second strategy, the standardization of construction, has been adopted by the housing ministry's Building Materials and Technology Promotion Council (BMTPC). In 2018, the BMTPC published a book titled *Compendium of Prospective Emerging Technologies for Mass Housing*. This book's 'Background' section notes that

> traditional building materials e.g. brick, cement, steel, aggregates, sand etc. […] are either based on natural resources which are finite in nature or energy intensive or emit greenhouse gases during production. Thus, the entire proposition of using these materials as usual will not be sustainable and environment friendly. Further, the construction technologies being practiced in

> India is cast-in-situ RCC beam-column construction[4] which is primarily slow track methodology and is subjected to time and cost overruns. Also, these constructions are labour intensive, which further hamper fast delivery, as there is acute paucity of unskilled labour force in cities. Therefore, it is prudent to take a paradigm shift from brick and stick approach. (BMTPC, 2018: 1)

Emerging reinforced cement concrete (RCC) technologies that have been successful globally in the last 10 years are demonstrated in the pilot housing projects. Some pilot projects are listed in the model projects. Both the BMTPC's book and the pilot projects advocate RCC construction types, such as the monolithic concrete system, precast concrete panels, and fast-track modular systems, among others. Bricks made of natural building materials (clay, stone) have been traditionally used in building envelopes due to their cooling effects in indoor spaces but are now diminishing in new construction practices (Vijayan et al., 2021). What is concerning is that the main focus of the BMTPC book and pilot projects – which keep cost, time, labour, and natural materials *low* for *low-income mass housing* – does not include thermal evaluation of building envelope materials. The shift from traditionally used natural materials (clay, sand, stone) towards concrete-heavy systems involves a significant change in the thermal performance of buildings, which directly affects the energy demand for space cooling.

A third strategy concerns the building codes: A key climate change policy tool, published a year after the BMTPC book, can be observed as the national ministries' next systematic step towards the standardization of mass housing buildings. It is titled *India Cooling Action Plan (ICAP): Operationalizing Space Cooling Recommendations* and was published in 2019 by the Ministry of Environment, Forest and Climate Change. Emerging from the *ICAP*, new building codes have been rolled out by the Bureau of Energy Efficiency (BEE). BEE's building code, the *Energy Conservation Building Code for Residential Buildings* (BEE, 2018) provides recommendations for achieving energy-efficient building envelopes in concrete construction. At present, recommendations to improve the thermal performance of concrete buildings are not included in this code. In future, new

4 Reinforced cement concrete (RC) frames consist of horizontal elements (beams) and vertical elements (columns) connected by rigid joints. Beams and columns are cast in a single operation in order to act in unison. See Ahmet Yakut, 'Reinforced Concrete Frame Construction', *World Housing Encyclopaedia*, EERI and IAEE, https://www.world-housing.net/wp-content/uploads/2011/06/RC-Frame_Yakut.pdf.

parts are planned to be added. Such steps suggest the acceptance, or even welcoming, of the shift from natural materials to concrete. But it does not ensure the climate adaptability of the PMAY-U mission's massive mass housing stock.

In sum, the three strategies raise critical questions that are currently not accounted for by the Indian housing ministry: How many dwelling units have been built without meeting the new thermal code? And how many households will be exposed to the uncertain risk of concrete's weak thermal performance? In absence of using traditional building materials with cooling properties, it is more essential than ever to carefully find ways to improve the cooling effect of concrete buildings and their immediate surroundings. Due to the increase in hard and heat-absorbing surfaces such as concrete, improving passive cooling in buildings is necessary to moderate not only the space cooling demand but also the urban heat island effect on the neighbourhood. I argue the new construction shift runs the risk of being inadequate for future climate necessities. However, in order to address such questions, more knowledge is necessary about the ways in which planning and construction are actually implemented, and about the ways in which households deal with the thermal qualities of new concrete buildings on a daily basis. The next section gives an overview of the approaches to socio-spatial investigation of architecture that address the above argument.

Socio-spatial investigations in post-occupancy evaluation: Current state of research

Since the early 21st century, socio-spatial investigation has emerged as a key strand of built-environment research. Based on the theoretical lens of environment-behaviour research,[5] it aims to capture the perspectives of end users with respect to social investigatory aspects, as well as the perspectives of building professionals in regard to spatial investigatory aspects. There is a wide range of environment-behaviour-based evaluation methods for assessing occupied buildings, including the PROBE methodology (Cohen et al., 2001), the

5 Environment-behaviour (E-B) research is a multi-disciplinary field that advocates a greater involvement of users and a more detailed consideration of user aspects in the design process. E-B research has knowledge overlaps with other approaches and terms such as 'environmental psychology', 'human-environment studies', 'human factors', 'behavioural architecture', and 'social ecology' (Kar and Sarkar, 2017).

Design Quality Indicator (Gann et al., 2010), the Achieving Excellence Design Evaluation Toolkit (Ruddock and Aouad, 2009), post-occupancy evaluation (Preiser et al., [1988] 2015; Williams et al., 2016; Hay et al., 2017), and socio-physical liveability (Sarkar and Bardhan, 2020). These examples illustrate how assessment surveys can be integrated into case-study-specific research questions. David Michael Gann, Ammon J. Salter, and Jennifer Whyte (2010) argue that there is a widespread gap in 'measuring design value' within the building design and construction industry. They emphasize that this is due to the varying nature of building attributes. These attributes are physical, such as light levels as measured in lux, but also perceptual, such as a feeling of warmth or comfort, which is subjective to every building user. This highlighted gap underlies the above-mentioned socio-spatial evaluation examples, and these examples explore methods of understanding the value of a building in relation to its design, and to the range of physical, emotional, and aspirational needs of its occupants. Such environment-behaviour-based evaluation methods are considered an important contribution to built-environment methodologies rather than a definitive technical solution.

The post-occupancy evaluation (POE) method has emerged as a key approach within the broader field of environment-behaviour research. Social scientists, designers, and planners use it to understand the experience of building users (Zimring, 2013). There are three identified types of POE – indicative, investigative, and diagnostic (Preiser et al., [1988] 2015, quoted in Cooper et al., 1991). The indicative type attempts to identify major functional failures and successes of a building in a general manner and is conducted by one person. The investigative type aims to allow more detailed monitoring of building performance. The diagnostic type attempts to find results that can be generalized to a series of buildings, and it employs a team of researchers. The indicative type of POE allows for quick, simple, small-scale investigations which can provide feedback on buildings' physical qualities that foster or impede the desired or necessary behaviours of building residents (Cooper et al., 1991). Not only does it allow data collection on multiple dimensions, but it also gives flexibility to adapt the survey questions as per the needs of an investigation and the studied case.

Even though earlier usage of POEs was seen as successful in the context of public buildings, offices, and care homes, and later seen useful in energy efficiency certification, usage of POEs in the context of architecture practice and particularly in the mass-housing context is rather limited. In the United Kingdom, use of POEs in building standards and certification has been established and includes POE integration into the building standard and procurement process (Hay et al., 2017), POE guidelines in the Royal Institute of British Architects (RIBA) handbook (Williams et al., 2016), and POE incorporated into green building certification in international building energy efficiency standards such as those from LEED, Passivhaus, and the Green Building Council. However, as Rowena Hay, Flora Samuel, Kelly J. Watson, and Simon Bradbury (2017) argue regarding the limited utilization of POE in architecture practice, 'there is little evidence that this body of research has transferred to the practice environment to close learning loops and ensure future projects are informed by a joined-up evidence base rather than the isolated experience of individual professionals' (Hay et al., 2017: 699). The authors further emphasize the role of architects in advancing POE to become a widespread and consistently embedded aspect of standard practice in the construction industry.

Summarizing the current state of research, an ambivalent picture can be painted: On the one hand, socio-spatial investigation with POE offers a wide range of design assessment opportunities. Yet on the other hand, uptake and transference of POE-generated data is limited in the architecture discipline. POE's use is established in cases of social housing in the United Kingdom, but it is especially limited as a tool in the context of low-income mass housing in India. The swift and small-scale indicative POEs (Cooper et al., 1991) could potentially be of high value in the rapidly materializing Indian social housing sector to quickly and systematically collect input. To complement the ministry's efforts, it is necessary to implement methodological interventions and critical lessons learned from model projects. For example, POE-based investigations can fill a related research gap in studies in order to systematically assess changing housing typologies and identify the evolution or integration of passive cooling design techniques. Such methodological interventions can take place with the active participation of local architects, engineers, and community-based actors. For this research, I used an indicative type of post-occupancy evaluation (POE) to investigate the case study in order to identify physical qualities of mass housing buildings that foster or impede desired behaviours of building residents. The case study and research methods are outlined in the next section.

Case study and research methods

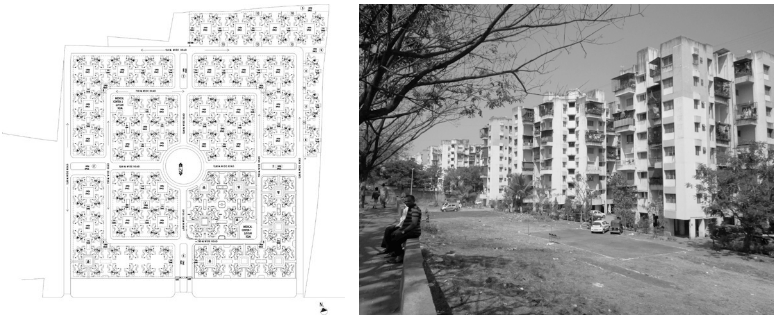
Located in 15 cities in 8 federal states, model housing projects in India vary from each other in density, size, design layout, building materials, and infrastructure. Mass housing projects range from 300 dwelling units in two-storey buildings (in-situ slum upgrading), to 1,650 dwelling units in four-storey buildings (slum relocation), to the largest project, containing 13,700 dwelling units in four-storey buildings (rehabilitation of flood victims). The design layouts and building arrangements of model projects contain various spatial elements and techniques, including medium to large public spaces, cluster layouts, courtyards within building clusters, and medium-rise buildings separated by adequately wide internal alleys (Jana et al., 2022). These spatial elements positively influence air ventilation, social interaction, community relationships, visual cognitive interaction, improved cycling opportunities, and walkability (ibid.).

I have selected the Gharkul housing complex, one of the 15 PMAY-U model projects, as an empirical case study on which I construct a narrative of *imagined outcome* and *actual outcome*. The Gharkul project is the densest among all the 15 model projects, featuring apartment buildings with the most storeys (Figure 1, right). It is listed as a model project for its efficient apartment design, cluster layout, adequate social infrastructure, and innovative, rapid construction technology (MoHUPA, n.d.). It is also a pilot project for a concrete-based construction technology used for the first time in an Indian public project (BMTPC, 2018). With the highest concrete density among PMAY-U model projects yet predicted to meet good planning standards for natural ventilation (ibid.), the Gharkul project holds key answers to concerns of whether the shift from natural materials to concrete is workable or not.

The project timeline – from the sanctioning of funds, to constructing infrastructure and buildings, to finally handing over apartments to inhabitants – spanned the years 2007 to 2022. Its site plan (Figure 1, left) contains 160 buildings in total, each featuring 7 storeys which rise above ground-level parking. Each apartment building is inhabited by 42 households, thus a total of 6,720 households live in the housing estate. Its 160 buildings are arranged in 40 clusters, which are each centred around a courtyard. The construction technology used in the Gharkul project, a monolithic concrete construction system using aluminium formwork, is described in the book *Compendium of Prospective Emerging Technologies for Mass Housing*, where it is categorized as '[s]uitable for low rise to high rise structures' (BMTPC, 2018: 10). The text then describes that the system is

> in place of traditional RCC framed construction of columns and beams and infill walls' and that 'all floors, slabs, columns, beams, walls, stairs, together with door and window openings are cast-in-place monolithically using [an] appropriate grade of concrete in one operation. The custom-designed modular formwork made up of Aluminium/Plastic/Aluminium-Plastic Composite is used for the purpose which facilitates easy handling with minimum labour and without use of any equipment (ibid.).[6]

Figure 1: Site plan of the Gharkul project (left); street view of mass housing buildings (right).



Source: Pimpri Chinchwad Municipal Corporation (PCMC) (site plan, left); Author (photograph, right).

This research employs a two-pronged qualitative research approach: an examination of national-level housing and cooling policies, and an empirical case study of the Gharkul project. Document research of housing and cooling policies informed the analysis of the housing ministry's aims and objectives. Qualitative spatial research of the Gharkul project was used to analyse the imagined outcome from the perspective of the project architects and engineers, based in Pune. The Gharkul case study allows an informed understanding of the actual qualities of the spaces as experienced by their inhabitants. Spatial research based on post-occupancy evaluation (POE) is

6 Language errors appear here as in the original source.

guided by and analysed through *technical*, *functional*, and *behavioural* dimensions (Preiser et al., [1988] 2015, quoted in Cooper et al., 1991). The technical dimension refers to the building design, construction, and cooling techniques; data for this dimension is drawn from interviews with the professionals involved in constructing and managing the Gharkul project. The functional dimension focuses on the spatial functions of the green and open spaces within the apartments and the wider community space; here, data is drawn from architectural drawings and field observations. The behavioural dimension examines the actions of the inhabitants in relation to using the space in a specific way; data on this is derived from interviews with inhabitants and a focus group discussion.

Spaces to be analysed for their functional dimension were identified based on a literature review of passive cooling design and field observations of the case study. Appropriate spaces having a dual quality of passive cooling benefits and greening potential were identified. Floor plans were the primary type of architectural drawing used to analyse spatial distribution and spatial measurements. My former professional experience as a practicing architect in the city of Pune was beneficial in understanding the data in these drawings. Nine in-depth semi-structured interviews of inhabitants were carried out in person by me. After the first round of in-depth interviews, an in-person focus group discussion, with 15 participants, was arranged to uncover information through open-ended questions. In addition, field observations were collected in the form of photographs, field notes, and short impromptu conversations with on-site and available persons. The primary analysis method is a qualitative content analysis, namely, reflexive thematic analysis (RTA), employing manual coding across datasets (Braun and Clarke, 2019). In this, iterative and non-linear phases of analysis, such as data familiarization, initial coding, theme generation, potential themes review, and theme defining, are followed (Byrne, 2021).

Imagined versus actual outcomes of standardized mass housing design: Key research findings

Arnab Jana, Ahana Sarkar, and Ronita Bardhan (2022), in their study performed using computational fluid dynamics (CFD),[7] predict the thermal performance of a number of PMAY-U model projects. These researchers view the built-volume techniques in the Gharkul project as representing good standards of housing planning. Cluster layouts with inner courtyards and, in particular, individual balconies, improve ventilation effectiveness, a major metric in reducing transmission of airborne diseases such as SARS and Covid-19 (Jana et al., 2022). In my empirical study of Gharkul, air ventilation and thermal comfort were noted by inhabitants as 'satisfactory', with one minor follow-up suggestion of faulty windowpanes that need maintenance; in total, evidence indicates a positive perception on these fronts. This correlates with the study by Jana, Sarkar, and Bardhan (2022), which provides computational evidence of how the passive cooling heat-transfer techniques designed in Gharkul's building volume can improve natural ventilation. With this data, I emphasize that Gharkul serves as a solid example of effective planning standards in reducing energy demand for space cooling. However, I further argue that the choice of concrete as a construction material poses serious future threats. To illustrate this, in the following sections, I lay out my research findings, structured in three dimensions: (1) technical – construction and cooling techniques, (2) functional – spatial functions of heat-transfer techniques in inhabitants' lives, and (3) behavioural – inhabitants' typical greening actions in using space.

Technical dimension: Construction and cooling techniques

The standardization of low-income mass housing is a key strategy that works effectively for the Indian housing ministry, the environment ministry, and the Building Materials Technology and Promotion Council (BMTPC) to pursue their goals. It enables the rapid construction of multiple apartment units;

7 Computational fluid dynamics (CFD) is the use of computers and numerical methods to solve problems involving fluid flow. Its applications in civil engineering extend to topics such as wind loading, structure vibration, wind and wave energy, ventilation, fire, and others. See David Apsley, 'Introduction to CFD', *The University of Manchester*, https://personalpages.manchester.ac.uk/staff/david.d.apsley/lectures/comphydr/introcfd.pdf.

a reduced energy demand for space cooling; and a technological shift that minimizes time, cost, labour, and natural materials – thus addressing the respective priorities of these three entities. At the case-study level, municipal goals, along with these national goals, provide other useful insights. As per the remarks of the interviewed municipal officer, physical infrastructure, such as water supply, sewage treatment, roads, storm water drainage, street lighting, and other electrification, as well as social infrastructure, such as a health care facility, a vegetable and convenience market, and a community centre, are the significant achievements of the Gharkul project. The officer believes that such infrastructure is essential but may have not been available in the previous living arrangements of many Gharkul households.[8] Another achievement, as viewed from the perspective of the structural engineer involved in the project, is having a uniform quality control of a large number of apartments, i.e. 6,000 units – an outcome that was not possible earlier, with traditional construction methods.[9] In the Gharkul housing project, however, as per the structural engineer, the use of a monolithic concrete construction system using aluminium formwork offered the desired quality control of construction as well as effective earthquake resistance.

In the energy efficiency building code document published by the Bureau of Energy Efficiency in 2018, two architectural solutions are provided to address cooling. The first is a set of simple-to-use thermal comfort calculation tools for new buildings.[10] The second is the use of passive cooling design techniques in new construction. The Gharkul project was constructed before 2018, before that building code was published. Yet empirical fieldwork conducted during this research reveals that the Gharkul architects did, nonetheless, consciously design spatial elements that maintain satisfactory levels of air ventilation. Heat-transfer passive cooling techniques identified in the Gharkul project include (1) a cantilevered balcony for each apartment, (2) open but sheltered ground-level areas for inhabitants' common use, in the style of Singaporean *void decks*, and (3) community courtyards in every four-building cluster. According to interviews with inhabitants, the aforementioned techniques have had positive functions in their daily lives. On the other hand, in mass housing projects newer than Gharkul but in the same

---

8 Structured interview with the municipal officer in charge of supervising the Gharkul housing project.

9 Structured interview with the structural engineer of the Gharkul housing project.

10 *Energy Conservation Building Code for Residential Buildings* (BEE, 2018).

PCMC region, housing density has increased. This has been achieved by an increase in the number of building storeys from 7 (in Gharkul) to 14 (in newer PMAY-U projects). However, the open spaces in housing estates and neighbourhood parks have not increased twofold, as the housing density has. This finding highlights that changes in the building code alone are insufficient in addressing the decrease in passive cooling spaces.

Figure 2: Concept drawing of a typical building cluster in the Gharkul project (left); courtyard in a building cluster (right).

Source: MoHUPA (n.d.) (concept drawing, left); Author (photograph, right).

Functional dimension: Spatial use of heat-transfer techniques in inhabitants' lives

In Figure 2, two phases of the Gharkul project's architectural process can be seen. Even though there are more drawings and processes in-between, these two depictions serve as a good representative example for the process of producing social housing in India. The first phase (Figure 2, left), depicted in a concept drawing, shows a cluster layout of four identical buildings set around an inner green courtyard. The central green square represents the inner courtyard surrounded by a paved concrete walkway. This captures the initial design vision before the construction process. Finally, the last phase (Figure 2, right), evidenced in a photograph, shows the cluster courtyard documented during fieldwork for this research in 2023. The inner courtyard envisioned in the concept drawing as an open green space is not green in the actual outcome. This is a major issue that is not represented in the drawings but revealed in the research findings. The inner courtyard instead contains water storage tanks and the underground building foundation, seen as raised concrete platforms (Figure 2, right). Due to these underground structures, some forms of vegetation are not possible. Major restrictions are imposed by the management authorities for greening and planting trees due to the serious risk of damage to the underground concrete structures by means of tree roots and potential water leakage,[11] even though inhabitants are inclined to greening these spaces. Consequently, the envisioned *green* spaces are ironically manifested as *grey* concrete surfaces.

A second issue that is not represented in the architectural process (Figure 2) but discovered in the fieldwork concerns the limits to barrier-free access to community space. As per fieldwork observations, interviews with inhabitants, and a focus group discussion, community space on the ground floor is the most multifunctional community interaction area in each individual building. Community members of varying age groups, genders, and social subgroups, individually or in groups, use parts of the spaces for formal and informal community gathering, playing, resting, and exchanging short conversations. The design problem is the limited elevator access. Existing elevators only serve alternate floors instead of serving all of the seven floors of the building. Even though it is not a common practice, this was done as a cost-cutting measure.[12] The implication of this design leaves half the building inhabitants with no barrier-free access to their own apartments. The inhabitants living on floors without direct elevator service have to use stairs to go down to a lower floor and then access elevator service. In addition to that, limited elevator access hinders less physically abled inhabitants, elderly people, and pregnant women living on floors without direct elevator service from traveling down to the ground-level community space as frequently as they would like. No barrier-free access is a serious burden in the daily lives of some inhabitants. Thus, the functional dimension of the research findings has revealed serious structural limitations to the future of greening and inclusive community life in the Gharkul project, which can have adverse impact on long-term residential liveability, community interaction, and sense of belonging.

11 Information recorded in surveys with inhabitants and during the discussion with a site engineer.

12 Information recorded in the discussion with a site engineer.

Behavioural dimension: Inhabitants' greening innovations in the concrete building envelope

Study of the lived experience of the Gharkul housing project was insightful in revealing the link between the lack of open green spaces and inhabitants' greening innovations. Dedicated open spaces in the Gharkul site are observed to be left unmaintained by the municipality and unused by inhabitants. However, the greening culture observed is noteworthy because it is particularly integrated into the concrete building envelope or surface. Figure 3 is a compilation of such greening examples integrated both into the concrete building envelopes and into inhabitants' daily lives.

Figure 3: Greening practices observed in building on street level (left); shaded street space (middle); use of balcony (right); Gharkul project, March 2023.

Source: Author.

In Figure 3 (left), despite the structural limitations of paved and concrete surfaces, a series of potted plants is used by inhabitants to create a green wall. This green wall serves as a design element that grants privacy from the adjoining street. It also provides vegetation cover, which is beneficial for its cooling effect. Animals such as birds and stray dogs have been observed sitting around such green areas for refuge during hot afternoons. Figure 3 (middle) shows a shopkeeper – who is also one of the interviewed inhabitants – set his makeshift tobacco shop in the roadside shelter provided by a medium-sized shade tree. Cool, shaded space in a hot afternoon is observed to be a space of exchanging short conversation between the shopkeeper and a mobile fruit seller. An action – of taking a break – suggests a behavioural dimension, which is influenced by the green and cool environment. This behavioural dimension is observed not only in humans but also in animals.

As another example, all of the interviewed inhabitants typically use their balconies as a private space (Figure 3, right). Spatial use includes storage, sewing, drying, and kitchen-related activities, as well as planting herbs and medicinal plants. The current design of the balconies offers inadequate solar shading, hence making the outdoor areas very hot. Almost all of the households have covered their balconies with inexpensive metal roofing, while some have covered one side with a green fabric wall. Some have used balconies for growing potted plants, turning them into private gardens that are also a shelter from harsh weather. There is a positive potential for introducing more of such cantilevered spaces in future designs due to their multiple benefits. Some of the most beneficial functions assessed also save ground space for other needed activities such as social gatherings, vehicle parking, and the planting of larger trees. Greening provides a private, cool haven in a scenario of everless inter-building space. Thus, inhabitants integrating greening within the concrete building envelope, the building surfaces, and their daily lives use it to gain essential aspects such as cooling, privacy, gardens, and hobby spaces. Greening also acts as a counterforce against a hot climate for inhabitants and animals alike.

Contingencies in the adaptation and greening of mass housing in the face of climate change

Turning to a discussion of the contingencies that emerge in Indian mass housing, I will structure this section around the two elements of contingency mentioned earlier: (1) the uncertainty emerging from a mismatch between the vision of the housing mission and the acceptance of the inhabitants, and (2) the possible inadequacy of newly built housing to further meet future climate necessities, for which existing measures will not be sufficient. From the case study of the Gharkul project, standardized monolithic RCC construction emerged as a low-income mass housing solution, arising from the national strategies of model projects and construction standardization. When understood in light of the historical background of these strategies, it can be seen that the central future threat that the Indian housing ministry has been addressing is the *reappearance of slums*. Globally and in India, slums have been defined by organizations, researchers, and ministries in various ways; however, one important aspect of slums that is invariably defined and observed is the *temporary* nature of their material condition. On the one hand, the structural system used in the Gharkul project drastically constrains any future adaptation in walls, ceilings, or foundations. Any small adaptation to these, if made, may damage the entire building's stability,[13] hence such modifications are prohibited and strictly monitored. The housing ministry, to avoid the reappearance of temporary slums in the cities, has constructed permanent housing units. However, as seen in the Gharkul case study, this *permanency* is manifested as *inflexibility*, and is a serious threat to the future adaptation of these buildings.

On the other hand, permanency can also provoke *flexibility,* seen in terms of the inhabitants' greening and shading innovations set within the inflexible concrete envelope and surfaces. This is evident in how inhabitants' shading efforts are seen on a majority of the 6,720 concrete balconies, implemented by using metal roofing or sometimes green fabric walls for additional lateral shading. In addition, flexibility can be viewed in terms of how inhabitants use and adapt the community space – the open ground-level community space and adjoining courtyards. It can be witnessed in how they are trying to grow small- and medium-sized trees in the periphery around concreted courtyards, to the degree tolerated by the strict municipality codes that control the planting of large shade trees. And it is seen in how they erect makeshift fabric roofs as a shading element above the same community and courtyard spaces during festival gatherings, children's birthday parties, and public holiday celebrations. This emphasizes that the balconies and courtyards of the Gharkul project – the heat-transfer techniques employed by the building architects much before the cooling action plan – allow inhabitants to be flexible within the inflexible concrete building envelope. Thus, in the new contingencies around cooling strategies, the existing best practices already employed by architects across many different Indian cities, which have become successfully adapted by inhabitants and integrated into their daily lives, should be effectively studied and supported.

In sum, one of the most pronounced challenges of standardized mass housing stock is adapting the housing form to the needs of the inhabitants, given the changing needs concerning the built environment of mass housing in India. Although existing policy tools and building codes provide technical solutions to address problems with new construction, they fall short of addressing the adaptation needs of existing housing stock. This raises a critical

13 Structured interview with the structural engineer of the Gharkul housing project.

question of structural inadaptability and inflexibility, which can lead to unavoidable building decay and, further, to an inevitable demolition instead of adaptation. In such a context, focusing on behavioural dimensions to building adaptability is essential. In addition, non-envelope or built-volume-related heat-transfer techniques (such as courtyards and open green spaces) are needed to be integrated into the new cooling action plan's code. In such a way, the newly built housing will not only be equipped with the existing successful measures but also be enhanced with the new cooling strategies to meet the future climate necessities.

Conclusion

Informed by the debate around whether mass housing projects may act as planned environments that reproduce or reshape impoverishment practices (Doshi, 2013), the overarching aim of this chapter was to gain a critical perspective on the Indian housing ministry's low-income mass housing. I selected one of the ministry's 15 model projects as a case study to locate the discrepancies between imagined and actual outcomes of the project, as seen through the lens of contingency. Two elements were identified as the main contingencies in such projects: (1) the uncertainty emerging from a mismatch between a housing mission's vision and inhabitants' acceptance of the newly built housing, and (2) the variables arising from the fact that newly built housing must meet future climate necessities, for which the existing measures will not be adequate. This framework of contingency has been beneficial in this enquiry in foreseeing that serious issues can arise if socio-ecologically advantageous heat-transfer techniques, such as community courtyards, and their associated behavioural actions, are left out of the new strategies. New policy tools and building codes are providing technical solutions to solve many problems of new construction, but they are limited in addressing the adaptations that existing housing stock requires. Similarly, the adaptation of new buildings is also excluded from strategic consideration in these policy tools and codes. Hence, the permanency of housing, even as it addresses the basic needs of housing, poses a threat of pushing low-income populations into the potential scenario of additional unforeseeable cooling costs in the future.

This research has concluded that the Indian energy ministry's *India Cooling Action Plan* (*ICAP*) presents technological innovation while also keeping technology uncomplicated and accessible to architects by means of new methods.

The *ICAP* is also observed to foster an attitude of learning in the Indian housing delivery system by allowing the realignment and updating of all existing, decentralized building and planning codes in order to adapt to changing energy needs. This openness to learning, however, must also apply when evaluating existing buildings in terms of inhabitants' daily lives. This research illustrates how, despite the poor-quality green spaces in the built manifestation of the Gharkul housing project, greening is well integrated within the daily lives of its inhabitants, who use it to gain essential aspects such as privacy, gardens, hobby spaces, and thermal comfort. Such behaviours must be viewed as innovations, and their potential in helping to avoid future building decay and abandonment must be evaluated. Moreover, the spatial characteristics that encourage such inhabitant-driven greening behaviours can also be used to shape and update new building codes.

A socio-spatial approach to investigating the built environment is acknowledged in this research as an opportunity to delve deeper into adaptability issues. This work can shed light on the material form of buildings in ways seldom undertaken in construction research and practice, as well as bring forward crucial questions and insights for practitioners to consider. In the social sciences, this type of empirical investigation can add to existing theories by supplying knowledge of observable phenomena; for instance, this allows for more specific and robust case studies and more focused testing in process tracing.[14] Post-occupancy evaluations and architectural design assessment, if further developed from existing methods and teachings, can provide definite direction for responsive and adaptable spatial production in low-income housing buildings. In future, a socio-spatial investigation of all 15 model projects could usefully inform new policies and design codes. This research views socio-spatial investigations as an opportunity for organizations to deal with contingencies in a more inclusive and comprehensive way.

14 For more on process-tracing methodology used as a theory-building method that uses initial empirical probing as an important step before engaging in a more focused testing, see Beach and Pedersen (2019).

References

Asimakopoulos, D. and M. Santamouris (eds.) (2013) *Passive cooling of buildings* (3rd ed.). Earthscan; Routledge, Abingdon.

Beach, D. and R.B. Pedersen (2019) *Process-tracing methods: Foundation and guidelines* (2nd ed.). University of Michigan Press, Ann Arbor.

Bhan, G. (2017) From the basti to the 'house': Socio-spatial readings of housing policy in India. *Current Sociology* 65.4, 587–602.

BEE (Bureau of Energy Efficiency) (2018) *Eco-Niwas samhita 2018/Energy conservation building code for residential buildings*. https://beeindia.gov.in/sites/default/files/ECBC_BOOK_Web.pdf.

BMTPC (Building Materials and Technology Promotion Council) (2018) *Compendium of prospective emerging technologies for mass housing* (3rd ed.). Ministry of Housing and Urban Affairs of the Government of India. https://bmtpc.org/DataFiles/CMS/file/PDF_Files/BMTPC_Compendium_ET_Sept2018_3rdEdition.pdf.

Braun, V. and V. Clarke (2019) Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health* 11.4, 589–97.

Byrne, D. (2021) A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality and Quantity* 56, 1391–1412.

Cernea, M.M. (1995) Understanding and preventing impoverishment from displacement: Reflections on the state of knowledge. *Journal of Refugee Studies* 8.3, 245–64.

Cohen, R., M. Standeven, B. Bordass, and A. Leaman (2001) Assessing building performance in use 1: The probe process. *Building Research and Information* 29.2, 85–102.

Coleman, A. (1985) *Utopia on trial: Vision and reality in planned housing*. Hilary Shipman, London.

Cooper, B.A., S. Ahrentzen, and B.R. Hasselkus (1991) Post-occupancy evaluation: An environment-behaviour technique for assessing the built environment. *Canadian Journal of Occupational Therapy* 58.4, 181–88.

Creswell, J.W. (2007) *Qualitative inquiry and research design: Choosing among five approaches* (2nd. ed.). Sage, Thousand Oaks, CA.

Dempsey, N., G. Bramley, S. Power, and C. Brown (2011) The social dimension of sustainable development: Defining urban social sustainability. *Sustainable Development* 19.5, 289–300.

Doshi, S. (2013) The politics of the evicted: Redevelopment, subjectivity, and difference in Mumbai's slum frontier. *Antipode* 45.4, 844–65.

Evans, G.W., N.M. Wells, H.Y. Chan, and H. Saltzman (2000) Housing quality and mental health. *Journal of Consulting and Clinical Psychology* 68.3, 526–30.

Gann, D.M., A.J. Salter, and J. Whyte (2010) Design quality indicator as a tool for thinking. *Building Research and Information* 31.5, 318–33.

Gupta, R. and M. Joshi (2021) Courtyard: A look at the relevance of courtyard space in contemporary houses. *Civil Engineering and Architecture* 9.7, 2261–72.

Hay, R., F. Samuel, K.J. Watson, and S. Bradbury (2017) Post-occupancy evaluation in architecture: Experiences and perspectives from UK practice. *Building Research and Information* 46.6, 698–710.

Jana, A., A. Sarkar, and R. Bardhan (2022) Evaluating well-being in low-income mass housing in India with specific reference to natural ventilation. *Area Development and Policy* 7.3, 267–92.

Kamal, M.A. (2012) An overview of passive cooling techniques in buildings: Design concepts and architectural interventions. *Acta Technica Napocensis: Civil Engineering and Architecture* 55.1, 84–97.

Kantakumar, L.N., S. Kumar, and K. Schneider (2016) Spatiotemporal urban expansion in Pune metropolis, India using remote sensing. *Habitat International* 51, 11–22.

Kar, Z. and A. Sarkar (2017) Exploring the role of environment-behaviour studies (EBS) in residential architecture: From literature review to field study. *International Research Journal of Engineering and Technology* 4.11, 409–18.

Marcuse, P. (1985) Gentrification, abandonment, and displacement: Connections, causes, and policy responses in New York City. *Journal of Urban and Contemporary Law* 28.195, 195–240.

MEFCC (Ministry of Environment, Forest and Climate Change, Government of India) (2019) *India cooling action plan*. http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf.

Mohajerani, A., J. Bakaric, and T. Jeffrey-Bailey (2017) The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. *Journal of Environmental Management* 197, 522–38.

MoHUPA (Ministry of Housing and Urban Poverty Alleviation, Government of India) (n.d.) *Best practices: Habitat planning and design for the urban poor*. https://www.naredco.in/notification/pdfs/Best_Practices_Habitat_Planning.pdf.

MoHUPA (Ministry of Housing and Urban Poverty Alleviation, Government of India) (2015) *Pradhan Mantri Awas Yojana: Housing for all (urban); Scheme* *guidelines*. https://data.opencity.in/dataset/pradhan-mantri-awas-yojana-housing-for-all-scheme-guidelines-2015.

Newman, O. (1973) *Defensible space: Crime prevention through urban design*. Collier Books, New York.

Preiser, W.F.E., H. Rabinowitz, and E. White ([1988] 2015) *Post-occupancy evaluation*. Routledge, London.

Ruddock, S. and G. Aouad (2009) *Creating impact in healthcare design: Assessment through design evaluation*. Paper presented at the Sixth International Postgraduate Conference in the Built and Human Environment, TU Delft, Netherlands, 6–7 April. https://www.irbnet.de/daten/iconda/CIB8993.pdf.

Sarkar, A. and R. Bardhan (2020) Socio-physical liveability through socio-spatiality in low-income resettlement archetypes: A case of slum rehabilitation housing in Mumbai, India. *Cities* 105, 102840.

Slater, T. (2009) Missing Marcuse: On gentrification and displacement. *City* 13.2–3, 292–311.

Vijayan, D.S., A. Mohan, J. Revathy, D. Parthiban, and R. Varatharajan (2021) Evaluation of the impact of thermal performance on various building bricks and blocks: A review. *Environmental Technology and Innovation* 23, 101577.

Williams, J.J., B. Humphries, and A. Tait (2016) *Post occupancy evaluation and building performance evaluation: Primer*. Royal Institute of British Architecture. https://riba-prd-assets.azureedge.net/-/media/GatherContent/Post-Occupancy-Evaluation/Additional-Documents/RIBAPOEBPEPrimerpdf.pdf.

Zimring, C.M. (2013) Post-occupancy evaluation: Issues and implementation. In G. Cranz and E. Pavlides (eds.), *Environmental design research: The body, the city and the buildings in between* (3rd rev. ed.), Cognella, San Diego.