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Low-income housing layouts under socio-architectural complexities: A parametric study for sustainable slum rehabilitation

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ABSTRACT

Lack of sustainable slum redevelopment guidelines in India is a policy gap that needs immediate attention. A rational design and planning route is necessary to ensure sustainability of the upcoming low-income (LIG) housing stocks. In this study, we performed a cross-sectional evaluation of LIG housing layouts through a socio-architectural and site-based wind-flow analysis route. We hypothesise that a better indoor environment in the LIG housing can be achieved through a better wind driven natural-ventilation in the living spaces, which is a function of the housing layout. Specific objectives of this study were: i) to investigate the influence of socio-architectural and geometric parameters on the LIG housing layouts; ii) to examine the effect of site-wind flow on LIG housing layouts using CFD simulations. BDD chawls of Mumbai were adopted as the case study. Results show that the current form of the LIG houses had a poor indoor environment and social interaction spaces, while the hypothesised iterated layout 'Form A' performed better in all the socio-architectural and wind-flow metrics that can promote relatively better quality of life. This study is a first-step approach for the development of regulatory guidelines in LIG housing design that is coherent to the context of the space.

1. Introduction

The concept of smart and sustainable cities has gained importance due to rapid global urbanisation and the need for sustainability in all aspects of the city (Ibrahim, Adams, El-zaart, Ibrahim, & El-zaart, 2016). Sustainable Development Goal 3 and 11 has further promoted the development of sustainable cities with an aim at improving the living conditions of the citizens to provide them with a better quality of life (Bardhan, Kurisu, & Hanaki, 2011; Bardhan, Kurisu, & Hanaki, 2015). However, due to the challenges at policy and social levels, the extent to which the local governments can address sustainability issues within a city remains unanswered (Bulkeley & Betsill, 2005).

UN-Habitat characterises slums as lack of durable housing, insufficient living spaces, lack of access to safe water at an affordable price, inadequate sanitation regarding access to private or shared public toilets and insecure tenure that entitles force evictions (UN-Habitat, 2007). In India, slums have been defined as those residential areas where dwellings are unfit for human habitation implicating in an inferior quality of life (QoL), as per Section-3 of the Slum Area Improvement and Clearance Act 1956 (Bardhan, Sarkar, Jana, & Velaga, 2015). National Urban Housing and Habitat Policy 2007 (MHUPA, 2007b) states mismatch between demand and supply of affordable housing units for the Economically Weaker Sections (EWS) and Low Income Groups (LIG) sectors and is a significant issue of sustainable development in India. This lack of affordable housing under the urbanisation pressure transforms cities into the hyper-dense agglomeration of EWS and LIG settlements in the form of urban slums. Nearly, 13.7 million households of urban India lives in slums (Census, 2011). The Government of India (GoI) has been trying hard to contain and transform such rapid expansion of slums in cities, since the introduction of the National Housing Policy (NHP) in 1994. However, such 'slum-free city' policy measures remain ineffective even today.

The National Urban Housing and Habitat Policy 2007 emphasises on earmarking land for EWS/LIG groups in the new housing projects, and ascertains the role of government in social housing through affordable housing programs like 'Housing for All-2022'(MHUPA, 2015); 'National Slum Development Program (NSDP) 1996-2006' (MHUPA, 2007a); 'Swarna Jayanti Shahari Rozgar Yojana (SJSRY) 1997' (MUAE, 1997); 'Valmiki Ambedkar Awas Yojana (VAMBAY) 2001' (MoUD, 2001), etc. These policies and programs have yielded positive results in providing

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Nomenclature

H	Height of the building (in m)
W_{canyon}	Canyon width (in m)
A_T	Plot area (in m^2)
P	Perimeter of the urban form (in m)
W	Maximum width of the plot (in m)
Pop_{UB}	Total population of the urban block
P_i	Perimeter of the shape/profile (in m)
A_F	Frontal plane façade area (in m^2)
$A_{positive}$	Total area of positive space (in m^2)
$A_{negative}$	Total area of negative space (in m^2)
S	Surface area of building (in m^2)
V	Volume of the building plot (in m^3)
e_{ij}	Connectivity of an edge in a space graph *G (V, E)*, where, *V* is the set of nodes defining places $\{vi \mid i = 1, 2, \ldots, n\}$ and *E* is the set of edges or links connecting them $\{vi, vj \mid eij, i,j = 1, 2, \ldots, n\}$
C_{ij}	Number of edges *(E)* to which a node *i* is directly connected

housing and habitat for the EWS and LIG, but its efficacy in the long run, remains a planning challenge (Bardhan, Sarkar et al., 2015). Additionally, there are no standardised methodologies for such efficacy studies in housing and habitat sector and remains a blind spot in India's habitat policy (Bardhan, Debnath, Jana, & Norford, 2018; Debnath, Bardhan, Jain, 2017). It is estimated that 80% of the housing stock is yet to be constructed in the coming 20 years (Bardhan & Debnath, 2016), out of which one-third of the shares would be exclusive for the EWS/LIG sections (MHUPA, 2015). Sustainable habitat guidelines for these settlements become a vital necessity to ensure the inclusive growth of the country. Besides, sustainable LIG habitats would provide energy efficiency in the residential sector, health security among the most vulnerable population groups and improve resiliency to climate change (Debnath, Bardhan, Jain, 2016; Debnath, Bardhan, Jain, 2017; Jana, Bardhan, Sarkar, & Kumar, 2016).

The novelty of this study lies in the cross-sectional approach of LIG housing policy determination under constraints (in this case, the LIG housing design was fixed). Here, the housing layout was parametrically studied by varying socio-architectural and geometric elements and was further coupled with site-based airflow analysis to investigate the suitability of a housing layout under socio-technical complexities. We hypothesise that 'a better indoor air quality through cross-ventilation would ensure a better quality of life in low-income tenement housing, which is a function of the site-layout'. Hence, our methodology transverse across socio-architectural and geometric metrics, along with a computational fluid dynamics (CFD) analysis of the site-based wind flow pattern around the housing layouts, for determining the most suitable LIG layout under design constraints. Specific objectives of this study were: i) to investigate the influence of socio-architectural and geometric parameters on the LIG housing layouts; ii) to examine the effect of site-wind flow on LIG housing layouts using computational fluid dynamic simulations. The more significant goal is to imbibe sustainability in urban renewal and rejuvenation program of the GoI, by generating a process-flow for LIG habitat design through data-driven design heuristics of the people and places. It would ensure that older LIG housing stocks of a city are not just reconstructed (MoUD, 2017). Instead, a retrofitting and re-designing route of urban rejuvenation is adopted to ensure sustainability in the process of LIG habitat development.

2. Background

The acknowledgment of 'adequate housing' concerning poverty alleviation and socio-economic progress led to the concept of social housing in international discourse since the 1970s. Historically, international housing policy has witnessed the emergence of two distinct approaches towards securing of low-income housing provision, namely 'provider paradigm' and 'support paradigm' (Ehebrecht, 2014). While 'provider paradigm' fosters the idea of technical provision of shelter, the 'support paradigm' cultivates the social aspects within the broader concept of housing. The provider model is quantitatively biased and hence has been criticised for being too consumerist-orientated, contributing to profit-maximisation, while neglecting endorsement of the human needs. On the other hand, the support paradigm provides efficient resource management for societal well-being. Arresting of slum proliferation in developing countries like India has mostly followed the 'provider' regime with less consideration to the socio-cultural aspects of informal life (Bardhan et al., 2018; Bardhan, Sarkar et al., 2015; Jana et al., 2016).

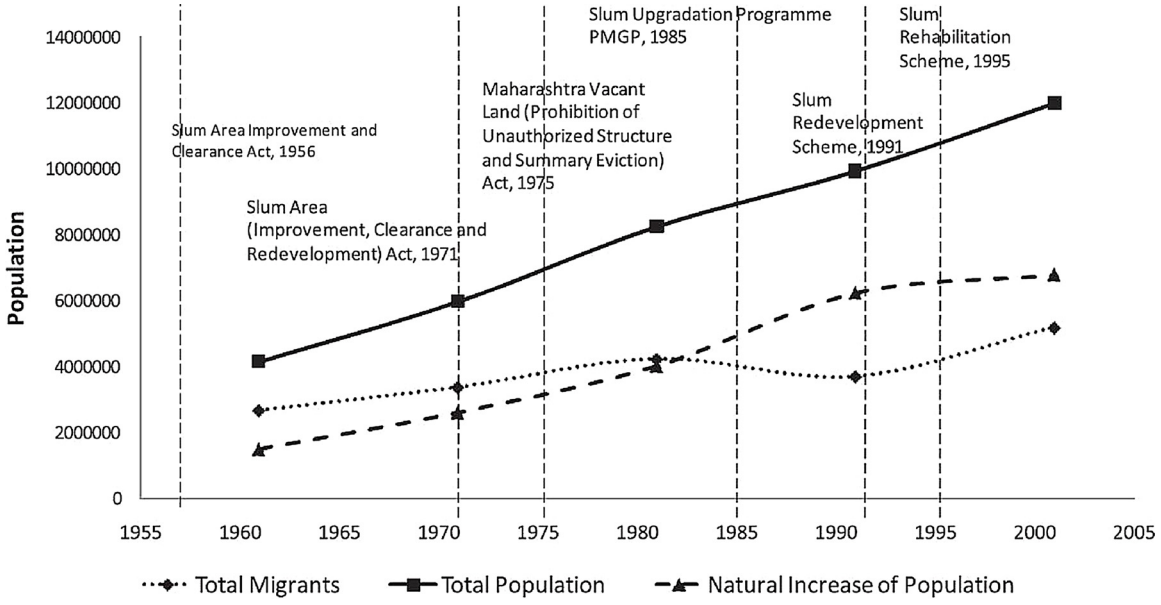

Fig. 1. Evolution of Slum policy in Mumbai, India since independence in 1947 (Bardhan, Sarkar et al., 2015).