Poster abstract: A data-driven design framework for urban slum housing - Case of Mumbai

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ABSTRACT

The current building assessment tools are limited to building performance analysis with respect to box models derived from the urban morphology of developed countries. Complex socio-technical issues associated with rapidly urbanizing cities like Mumbai are often missed. Here, we forward a conceptual framework for designing slum habitation adheres to norms of energy, health and environmental sustainability. This can enable in designing slum rehabilitation projects such that they are not only energy efficient, but are also acceptable to the occupants. This conceptual framework attempts to bridge the missing link currently existing in the early design stages of slum rehabilitation projects. The proof of the concept is a work currently in progress, hence, here, we only elaborate on the conceptual framework exemplified through three cases of slum rehabilitation houses in Mumbai.

1. INTRODUCTION

Slums are the result of rapid urbanization and unplanned industrialization in Mumbai. They are characterized by ultra-compact sprawling of ill-built houses, lack of basic life amenities, and have a huge impact on the energy, health and environmental sustainability of the city [1]. As per 2001 census, more than 50% of the city's population lived in the slums; with a marginal decrease to 41.9% in the last decade [2]. In order to improve the quality of life in these slums, the Government of India, came up with the slum rehabilitation program, where the horizontal stratification of slums was converted to vertical high rise housing, with the objective of providing better housing and healthier built environment [1].

Slum rehabilitation projects envisions to free land by reallocating the horizontal slums to vertical towers [2]. However, due to lack of literature, the performance of these vertical rehabilitation houses in terms of access to fresh air, daylighting energy efficiency and health impacts of such housing is still unknown. Here, we propose a data-driven conceptual framework to enable sustainable slum rehabilitation such that the basic sustainability of health, energy and well-being can be maintained, as per the UN-Sustainable Development Goal (SDG)-11: Make cities inclusive, safe, resilient and sustainable [3].

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The framework will provide much needed design strategies right from the early design stage, such that minimum retrofitting is required to maintain a desirable indoor environment.

2. CONCEPTUAL DESIGN FRAMEWORK

The conceptual framework is derived from three basic needs of the slum habitation: energy, health and indoor environment sustainability. In other words, the houses are so compact that, there is little air exchanges between the rooms, little penetration of daylight and the walls are usually covered with molds and fungus. Thus, occupants turn on the lights throughout the day, use exhaust fan and suffer from chronic skin and respiratory diseases [4].

Hence, it was evident that the framework must include these three elements: energy, health and indoor air quality, as a bottom up design strategy, as featured in [5], [6]; along with the human-environment dynamics to facilitate an eco-feedback mechanism [7], [8]. This design algorithm is illustrated in Figure 1.

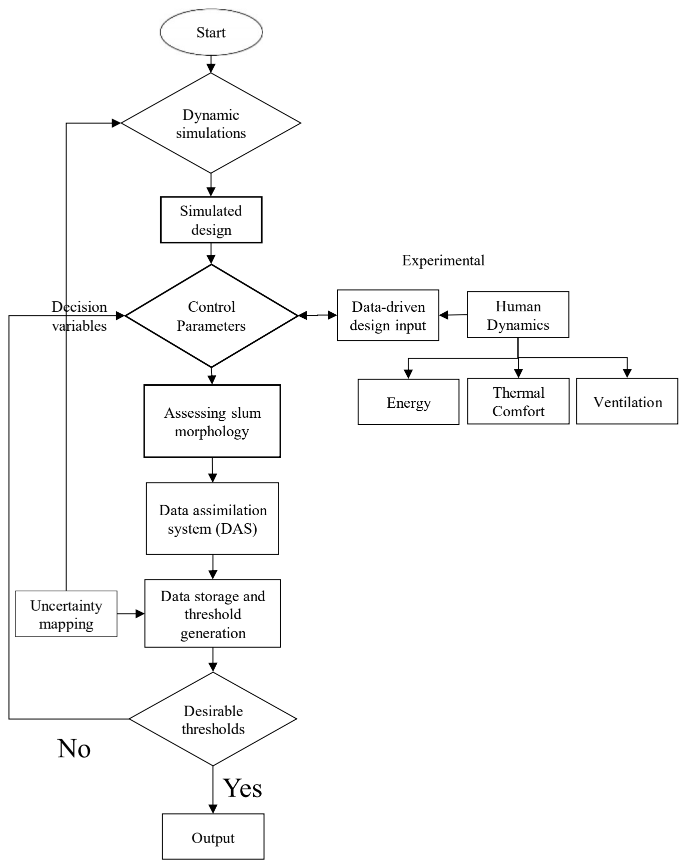

Figure 1. A conceptual design-flow for sustainable slum habitation design.

3. DATA ACCUMULATION AND ACQUISITION

The urban slum morphology of Mumbai is traditionally horizontal while, the proposed slum rehabilitation projects are vertical settlements (see Figure 2). The inherent transition of the slum settlement from horizontal to vertical form, calls for a data driven study.

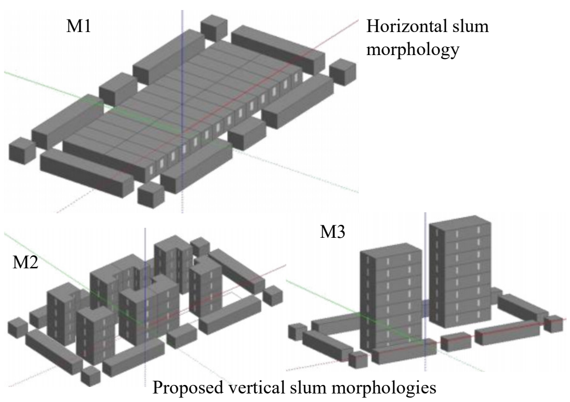

Figure 2. Slum morphologies in Dharavi, Mumbai, India.

Here, we had deployed temperature and RH sensor (HOBO Onset UX100-011) along with light and occupancy sensors (HOBO Onset UX90-006), to record thermal comfort and energy usage in the slum houses. This adds to the critical component in human dynamic modelling in building performance analytics, and is expected to fill the gap between demand side energy analysis and the desirable indoor environmental conditions like indoor operative temperature levels, and light levels.

This design algorithm can address the granularity of the energy use and thermal comfort data in these slums, such that they can be modelled using eco-feedback mechanisms. This step will enable threshold generation, uncertainty analysis and derivation of critical design variables, in a socially and technically inclusive manner. Figure 3 represents the actual depiction of the slum built environment.

Figure 3. Slum built environment (Actual field photo).

4. EXPECTED RESULTS

This methodology is expected to give planner and building scientists a first-hand design toolkit for slums, such that the greater goal of making human-settlement inclusive, safe, resilient and sustainable as per the SDG-11 [3]. However, this framework can fulfil several objectives of understanding cities with respect to their energy use and morphology.

The data acquisition from the sensors can provide essential inputs for large scale slum habitat modelling, which can have greater inferences in terms of urban heat island effect and climate change impact. In terms of energy sustainability, a new approach towards demand side management based on user behavior and urban morphology can be devised.

The immediate work includes modelling the slums in Mumbai and assess them from the lens of energy usage, thermal comfort and indoor air quality. The monthly energy consumption bill of the slum dwellers will indicate the energy usage, the temperature and RH sensor data will help in deriving the adaptive thermal comfort thresholds and air exchange rates in the houses will be the surrogate for indoor air quality.

5. ACKNOWLEDGMENTS

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