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A SYSTEM SIMULATION-BASED APPROACH FOR SUSTAINABILITY EVALUATION AND BENCHMARKING OF BUILDINGS

Ann Francis

Department Civil Engineering
Indian Institute of Technology Bombay
Powai, Mumbai
Maharashtra, INDIA-400076

ABSTRACT

The building sector significantly impacts the economic, social, and environmental dimensions of sustainability. However, the building sector lacks a suitable sustainability assessment and benchmarking mechanism that evaluates the tradeoffs among the three pillars while incorporating the time-induced changes in building characteristics. Hence, systems thinking that accounts for complex systemic behavior is ideal for solving sustainability problems. Therefore, the research proposes a methodological framework for benchmarking the sustainability of buildings using system dynamics modeling and simulation. System simulation enables forecasting the sustainability performance of a building while evaluating numerous improvement scenarios as well. Furthermore, a vast dataset is generated through a series of simulations of numerous building types. This dataset is then used to develop a benchmarking scale against which the performance of different buildings is defined. Such a simulation-based framework would enable overcoming the challenges associated with the data-intensive, multi-faceted and complex nature of building sustainability evaluation.

1 INTRODUCTION

Due to the building sector's major impact on social, economic, and environmental sustainability, it is crucial to set the right policies and targets to meet global climate targets and sustainable development goals. Hence, sustainability assessment and benchmarking are gaining significant attention in the building sector. Although there are several frameworks/tools available for sustainability assessment (Ness et al. 2007), most of them lack a holistic approach and do not account for the social and economic impacts nor the time-induced changes in building characteristics with time (Francis and Thomas 2022a). Furthermore, these sustainability assessment mechanisms do not define sustainability from the perspective of achievable targets or benchmarks based on comparison with other projects of a similar kind. Sustainability, being multi-faceted, requires a data-driven strategy and systematic consideration for benchmarking performance. Therefore, this research proposes a simulation-based framework for building sustainability benchmarking using systems dynamics approach that handles non-linear, uncertain, multi-feedback, complex, and dynamic systems.

2 RESEARCH METHODOLOGY

To enable assessment of the building, the various building and sustainability parameters are modeled and simulated using a multi-method simulation software Anylogic (Version 8.5.2). The first step involves data collection, which includes collecting the various building-related inputs (as shown in Figure 1). These input parameters compute the impacts across all the sustainability pillars using suitable indicators (as shown in Figure 1). The system dynamics interface then computationally models and captures the interdependencies

between these inputs, impacts, and indicators. The principles proposed in Francis and Thomas (2022a; b) are used to develop the system dynamics sub-models. These models are simulated to quantify the sustainability performance of different buildings. Post the base-case simulation, several policy scenarios and interventions are introduced into the framework to understand the possible sustainability improvement measures. After generating a large dataset of building scenarios, a building sustainability index (BSI) is computed for each scenario. The methodology recommended by the United Nations (UN) for calculating the composite sustainability development goals (SDG) index is utilized for the same. Based on the BSI computed for these several thousand scenarios, the high, low, and medium sustainability threshold for projects are defined. Further, the test projects are tested against this scale to understand their performance based on the benchmarks developed.

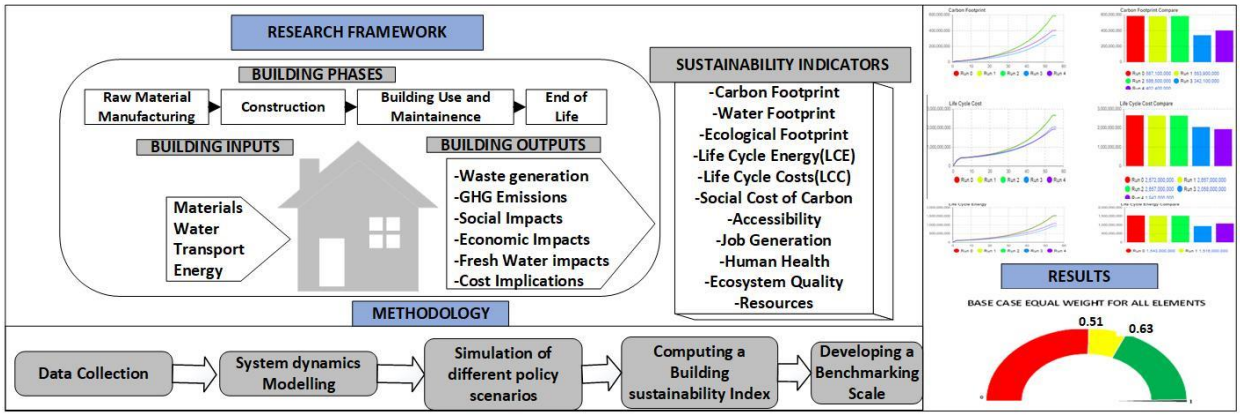

Figure 1: Research Framework and Results

3 RESULTS AND CONCLUSIONS

Thirty-five affordable housing projects across India were chosen as the case study to demonstrate this framework for which a set of policy interventions were simulated, thereby generating 21000 (35 X 600) scenarios (sample results in Figure 1). Based on the results of the simulation, a benchmarking scale was defined with high (green), medium (yellow), and red (low) sustainability with the threshold values derived, as indicated in the bottom right of Figure 1. Further, building projects are chosen, simulated, and evaluated against this scale to understand their sustainability level. Thus this research proposes a modeling and simulation-based approach for sustainability assessment to overcome the challenges associated with voids in data availability, complexity, and dynamism in the building sector. Therefore, this paper addresses the need for sustainability benchmarking that follows a combination of top-down and bottom-up approaches that are ideal for achieving policy targets. Hence, apart from policy analysis, system dynamics applications could be extended to standardizing and benchmarking sustainability performance in the building sector. Such a framework helps achieve tangible sustainability goals in the building sector, thereby enhancing the contribution to overall sustainable development.

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