Literature Review on Efficient ADU Design Simulation

Kevin Syhavong

Kennesaw State University
Email: ksyhavon@students.kennesaw.edu

***Abstract*—This literature review examines research relevant to the simulation of Accessory Dwelling Units (ADUs) design and placement. The review focuses on methodologies such as discrete-event simulation (DES), energy modeling tools like OpenStudio and EnergyPlus, GIS-based zoning analysis, cost estimation, and policy research. Identifying research gaps allows us to refine our simulation model to provide a more optimized approach to ADU feasibility assessment.**

I. Introduction

The rise of housing shortages and increasing urban density have led to a growing interest in Accessory Dwelling Units (ADUs). ADUs provide a sustainable and cost-effective housing alternative. However, optimizing ADU placement and design requires careful consideration of zoning laws, property constraints, energy efficiency, and construction costs. This literature review synthesizes key research in the field to develop a robust simulation model for ADU feasibility analysis.

II. Literature Summary

Summarizing and analyzing prior studies provides the foundation for designing our ADU simulation model.

A. Discrete-Event Simulation for ADU Design

Discrete-event simulation (DES) has been widely used in construction planning and urban design optimization. Basically, it is a step-by-step digital twin of the real-world process that only updates when an important event happens, such as the completion of an ADU's foundation or plumbing system. Instead of simulating every second, DES focuses on key events, allowing for efficient resource allocation and scheduling. This approach is useful in ADU construction, where different phases—like permit approval, site preparation, and material deliveries—must be optimized to reduce delays and costs. Studies show that DES effectively models sequential construction steps, cost estimation, and resource allocation by simulating various scenarios, such as labor shortages, material delays, and zoning restrictions. Additionally, DES is used in urban planning to evaluate the impact of ADUs on traffic flow, public utilities, and housing density [1], [2].

B. Energy Modeling for ADUs

Energy efficiency is a key factor in ADU design. Energy modeling is a simulation-based approach to predict energy consumption based on design, materials, climate, and appliances. Instead of building first and testing later, energy modeling allows for testing different ADU configurations before construction to optimize efficiency, cost, and sustainability.

Several tools are commonly used for energy modeling in ADUs:

- **OpenStudio**: Developed by the U.S. Department of Energy (DOE), this tool integrates with **EnergyPlus** to simulate HVAC systems, insulation, and solar exposure.
- **EnergyPlus**: A widely used simulation engine that predicts energy use based on **weather conditions, materials, and HVAC performance**.
- **BEopt**: This tool is valuable for modeling both **energy efficiency and economic feasibility**, helping designers choose **cost-optimal solutions**.
- **Passive House Planning Package (PHPP)**: Used for designing ultra-energy-efficient ADUs that rely on passive heating and cooling strategies.
- **ResStock and ComStock**: Large-scale analysis tools from NREL that assess **housing energy demand across multiple units**.

Recent research supports the application of energy modeling to ADUs. For example, [3] discusses advancements in **building energy modeling frameworks**, offering insights into improving the energy efficiency of ADUs. Another study, [4], highlights how **climate-responsive design choices** can significantly reduce **long-term operational costs** for ADUs, reinforcing the need for energy modeling in the design phase.

C. GIS and Property Constraints in ADU Placement

Geographic Information Systems (GIS) are instrumental in evaluating optimal locations for Accessory Dwelling Units (ADUs) by analyzing property dimensions, zoning regulations, and environmental factors. A study focusing on Los Angeles revealed that ADUs are less prevalent on larger parcels with newer homes and in densely populated areas near central business districts, airports, and beaches. Conversely, ADUs are more commonly found near commercial districts, light-rail stations, and educational institutions. The same study found that the presence of an ADU can increase a property's assessed value and selling price by approximately 7–9 percent [5].

In addition to permitted ADUs, there is a significant number of unpermitted, informal ADUs. Research utilizing computer vision and human annotations estimated that, in

San Jose, California, there are approximately three to four informal ADUs for every formal one. These informal units are more likely to be found in diverse, densely populated, and overcrowded neighborhoods. This prevalence of unpermitted ADUs highlights the need for policymakers to consider both formal and informal housing developments when addressing housing needs [6].

By leveraging GIS-based zoning analysis, planners can ensure that ADU placements optimize space utilization while adhering to regulatory frameworks. This approach not only aids in compliance with existing regulations but also provides insights into areas where policy adjustments could facilitate increased ADU development, thereby contributing to alleviating housing shortages.

D. Cost Estimation and Feasibility Analysis

Economic feasibility is a critical component in Accessory Dwelling Unit (ADU) development, encompassing detailed cost estimation and comprehensive feasibility analysis. Accurate cost estimation provides insights into construction expenses, labor costs, and material pricing, which are essential for informed decision-making.

Various methods exist for calculating ADU costs. One approach involves pricing a project based on unit costs for functional areas, allowing for a detailed breakdown of expenses associated with different components of the ADU. This method enables developers to identify cost-intensive areas and explore potential savings [7].

Feasibility analysis further aids in optimizing design choices to align with cost-efficient construction models. By incorporating financial simulations and comparative cost analyses, developers can evaluate various ADU prototypes to ensure economic viability. Additionally, studies on return on investment (ROI) and financing options, such as government incentives and private lending, contribute to a comprehensive understanding of ADU feasibility [8].

In summary, thorough cost estimation and feasibility analysis are indispensable in ADU development. They not only ensure that projects are economically viable but also help in identifying opportunities for cost savings and financial optimization.

E. ADU Zoning Laws and Policy Research

Legal frameworks and zoning policies significantly influence Accessory Dwelling Unit (ADU) construction, affecting approval processes and construction timelines. Understanding these regulations is crucial for stakeholders aiming to navigate the complexities of ADU development.

A comprehensive study examined the challenges and opportunities surrounding ADU development, highlighting how local zoning laws can either facilitate or impede the construction of these units. The research emphasized the importance of aligning local policies with state mandates to promote ADU adoption [9].

Another study analyzed local ADU policies in Los Angeles County, revealing that despite state laws promoting ADUs, many cities maintain strict regulations that affect the approval and construction processes. The study found that local ordinances often impose additional requirements, such as parking mandates and design standards, which can deter homeowners from pursuing ADU projects [10].

Understanding policy trends is essential for ensuring compliance and predicting future regulatory shifts that could affect ADU deployment. By staying informed about both state and local regulations, stakeholders can better navigate the complexities of ADU development and advocate for policies that support the growth of this housing option.

In summary, navigating the complex landscape of ADU zoning laws and policies requires a thorough understanding of both state and local regulations. Staying informed about policy trends and engaging with local planning departments can aid in ensuring compliance and anticipating future regulatory changes that may impact ADU development.

III. Conclusion

This literature review provides a foundational understanding of ADU design and placement methodologies. It highlights key research contributions and identifies areas where simulation models can bridge gaps in feasibility analysis. Future work will focus on refining the simulation model based on the insights gained from this review.

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