EVALUATING THE RELEVANCE OF COMPUTATIONAL DESIGN IN ARCHITECTURE AS A VIABLE RESPONSE TO THE AFFORDABLE HOUSING CHALLENGE

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ABSTRACT

The challenge of affordable housing is ever present in cities today. There is an urgent necessity for this problem to be addressed based on the adverse effects of continuous rapid urbanization. To achieve livable, responsive, resilient, and sustainable cities, architects and designers must create diverse, equitable, affordable, and quality housing for the urban population. The supply deficit is the most significant aspect to address on the affordable housing front. This paper investigates the potential of utilizing computational design tools – specifically generative design systems (GDSs)– in affordable housing design to facilitate its adoption in the industry through design concepts that lead to supply increases.

The computational design paradigm has been important to the architectural field, particularly in the last two decades, and continues to establish its relevance as a notable innovative architectural design method. However, the field still needs to be explored more. As such, there is much room to explore its potential applications and the optimal utilization of computational design tools to achieve desired outcomes. The methodology of this paper is based on the focused literature review regarding the state-of-the-art in various applications of computational design in the architectural design process to determine which methods can be similarly adapted towards affordable housing design.

This paper explores the relationship between designers and end-users during the design process of affordable housing. It concludes that applying GDSs in the design process facilitates collaborative housing design, a concept vital to solving the affordable housing challenge.

KEYWORDS _ *affordable housing, computational design, generative design, collaborative housing, sustainable design*

INTRODUCTION

Maclennan & Williams define affordability in housing as being "concerned with securing some given standard of housing (or different standards)" at a price or a rent that does not impose, in the eyes of some third party (usually government), an unreasonable burden on household incomes. (Maclennan & Williams 1990, p. 9). It is clear from this definition that alongside the price or rent of housing, two key aspects determine the level of affordability in housing. One is a standard quality of housing, and the other is a standard, reasonable ratio of the price of housing consumption to household income. (Haffner & Helyen 2011). For the purposes of this paper, the focus will be kept on the standard of housing quality. Only by establishing a standard for housing quality can it be possible to evaluate if housing is genuinely affordable. Factors like over-consumption and under-consumption affect whether housing is designated as affordable, and the quality of housing defines these concepts. (Haffner & Helyen 2011). Generative design systems (GDSs) can be considered collaborative partners that utilize the computational capabilities of computers in the exploration of various design iterations. (Mukkavaara & Sandberg 2020). This study explores the results of applying a combination of GDSs in establishing a standard for quality housing.

AFFORDABILITY THROUGH DESIGN

The quality of housing should be considered first as a design issue, as it is through specific design criteria that we can assess the quality of housing. The concept of Existenzminimum (minimum dwelling) was developed in Germany in the early twentieth century. It plays a vital role in the design of affordable housing as, when it was developed, it aimed to establish a standard dwelling considering evolving household dynamics, lifestyles, and technological progress. The concept was based on spatial optimization and the definition of minimum standards (Brysch et al. 2023). The design criteria that characterized the Existenzminimum worked to reduce building costs while also improving its quality, resulting in affordable housing. (Brysch & Czischke 2022). Brysch (2019) critically analyzed how the Existenzminimum design principles are used in contemporary affordable housing designs, summarized in the following lines.

Innovation and Cost-Effectiveness in Construction: Prefabrication and Modular construction are vital factors in affordable housing construction, as they enhance flexibility and customization. Combining modular construction with various collaborative approaches that employ end users or residents in completing the design process is common among contemporary projects. Environmental sustainability must also be given much attention as resources used, and energy design strategies may have critical long-term effects.

Minimum Quality Standards: Minimum quality standards in affordable housing are connected to the spatial design, services, resources, and construction finishes. The concept supports adopting a new idea of 'quality of life' that opposes the modern consumerism mentality. The ideas explored in many cases have been to deliver somewhat unfinished buildings, which enables residents to customize their spaces resulting in affordable access to good quality housing when compared to the market while maintaining individuality. Some examples of innovative solutions for achieving the minimum per spatial dimension are the "Tiny House Movement" and collaborative housing. In both approaches, the end-users play an active role in the design process. The resulting design is based directly on the needs and demands of the residents, who can define their own minimum standards more accurately in contrast to a developer-led project.

Redesign of Domestic Layout: The new domestic layout is designed based on shifting consumption models and evolving household dynamics. A significant reason for this is a participatory design process that involves residents collaborating with architects and developers in project designs. The minimum adaptability requirements being met is an essential component of this aspect. Many concepts and approaches supporting this view the building as a continuous process rather than

a finished project. While there remain barriers that complicate the normative adoption of these concepts, the results would be constantly changing spaces.

Relationship between Architecture and the City: It is believed that the effects of collaborative housing spread from the immediate neighborhoods to the city level in a progressive manner. There is a less strict line between the private and public, as community interaction is encouraged locally. The quality is subject to appropriately resolved interaction between the interior and public neighborhood spaces. It is also essential to consider the existing cityscape as many opportunities for affordable housing will be found in refurbishing the current housing stock or the adaptive reuse of buildings.

Community Building and Social Concern: The need for affordable housing is no longer restricted to low-income and vulnerable groups but also to middle-class households facing a decreasing standard of living. In this vein, collaborative and cooperative housing are alternatives to social housing. The role of collaborative housing in increasing social interaction is also being researched. Generally, it leads to the idea of design as a dynamic and participatory process that considers the changing needs of users. It focuses on the differences in households and lifestyles rather than providing a general design that residents need to fit into. Thus, residents are involved from the beginning of the design process and work alongside professionals to make design decisions.

All the design principles listed point strongly to the involvement of the end-users (residents) in the design process, ultimately saving costs and increasing affordability. In the modern day, this concept is encompassed in what is called Collaborative Housing.

COLLABORATIVE HOUSING

Collaborative housing can refer to "projects characterized by resident participation and collaboration with professionals in the design phase, aimed at creating housing projects in which residents intentionally share spaces." (Brysch & Czischke 2022). Brysch & Czischke (2022) developed an analytical framework to identify the design criteria influencing building costs in collaborative housing. This was relevant in assessing how decisions made during the design phase of collaborative housing play a considerable role in reducing building costs and increasing affordability. For their purposes, building costs refer to expenses from both project design and construction phases. (Brysch & Czischke 2022). Some of the factors developed are highlighted and summarized below.

Minimum standards: Residents can define their minimum standards for space and quality within the legal boundaries, sometimes contesting them. They determine the desired areas, domestic functions, and level of finishing based on their priorities. In contrast to mainstream housing, where they would receive finished products based on conventional standards, they can actively participate in the design process and accommodate their specific needs and aspirations. CH residents often move into unfinished buildings, intending to complete the spaces and surfaces later. The private units in CH projects are typically minimized to the legally accepted minimum, enabling the inclusion of collective spaces without increasing construction costs. The cost reductions, however, come from the reduced number of appliances in the private sphere.

Housing typology: The building costs of collaborative housing are influenced by the building's configuration, shape, and height. Its internal layout is often based on smaller private units and collective spaces, as well as the flexibility and adaptability of the spaces. At the same time, its circulation systems are compact and effective in spatial distribution. It is crucial to balance the private and collective spaces to control costs and foster values like social interaction, sharing, and community building.

Construction approach: Collaborative housing projects consider the building an ongoing process, as end-users can change and expand their housing units. The residents can complete various construction elements hands-on through Do-it-yourself or Do-it-together processes. Labor savings

in construction work and white-collar tasks promote the potential reduction of costs. Collaborative housing also encourages innovative construction solutions to achieve high sustainability standards.

Participation and decision-making: The participation of the end-users in the design phase can differ in intensity; however, collaboration between residents and professionals is the norm in collaborative housing. When user participation is high, collective decisions are made in almost the entire design scope. Where there is medium or minor participation, professionals generally make the final design decisions while considering the residents' preferences. The pitfalls of this process are increased potential conflict among residents and the time needed to come to a consensus. Figure 1 shows what can be considered a typical process of consensus-based decision-making.

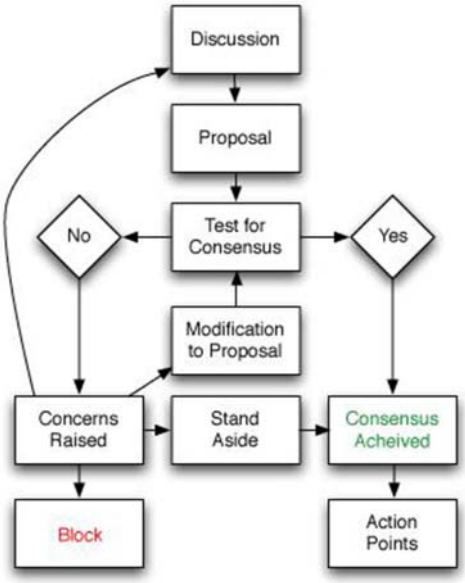

Figure 1: Consensus-flowchart.png - By grant horwood, aka frymaster http://en.wikipedia.org/wiki/Image:Consensus-flowchart.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1712925

Time: Collaborative housing is known for its lengthy and time-consuming processes. The time aspect must be considered from many different views, such as the time residents volunteer to work on the project, the time it takes to reach a consensus, the time it takes to carry out tasks, and the time it takes to build community and internal solidarity.

When utilized in collaborative housing, the factors above contribute to reducing building costs and increasing affordability. (Brysch & Czischke 2022). However, suppose this process is considered long and tedious. In that case, it will discourage the adoption of the collaborative housing concept on a broader scale, thereby limiting a real proponent for solving the housing crisis. This is where Generative Design Systems (GDS) come into the picture. The proper utilization of GDS during the design process has something to contribute to each design factor, which should improve the entire design and construction process.

GENERATIVE DESIGN SYSTEMS

Generative Design can be defined as "a design approach that uses algorithms to generate designs." (Caetano et al. 2020). Through generative systems, designers can use computational power to generate and evaluate multiple design iterations quickly and efficiently, which will most likely lead to creating and

selecting an optimum or near-optimum design. (BuHamdan et al. 2021). Among the main objectives of generative design systems are the ability to explore larger design solution spaces, facilitate design generation, reduce cost, and achieve optimization, accuracy, and consistency. (Singh & Gu 2012).

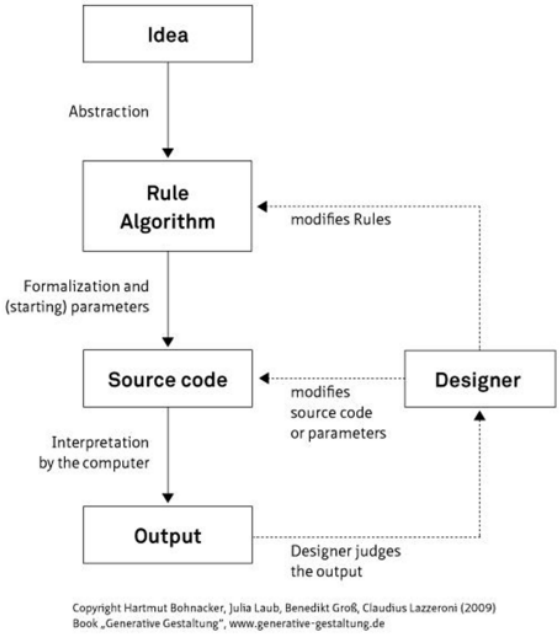

Figure 2: Generative Design Process - By Hartmut Bohnacker - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=9484507

Applications of Generative Design Systems in the AEC Industry

Generative systems have various applications in the field of architecture today. In this section of the paper, the main applications relevant to collaborative housing will be highlighted and discussed in terms of how they can contribute to factors listed in the previous section and, thus, affordable housing.

Program generation: The most common use of generative systems in architecture is developing layouts that meet architectural program requirements. (BuHamdan et al. 2021). Regarding CH, GDSs have been specifically used to generate layouts when the design must fulfill several constraints, from end-user preferences to socio-[particular]spatial constraints like privacy and accessibility. This is particularly important as residents are encouraged to define their minimum standards in CH. This also relates to the participation and decision-making aspect of CH. After professionals have generated layouts based on residents' preferences, residents can make informed decisions on tangible design iterations resulting in a smoother process. (Fisher-Gewirtzman & Polak 2019). Time is also saved, as the long time it usually takes to reach a joint agreement (Brysch & Czischke 2022) is now drastically reduced as it is more likely to reach an optimal solution quicker based on the multiple iterations produced.

Structural elements' layout: GDSs have been used by practitioners in what can otherwise be a taxing, repetitive, and complex process of determining the near-optimal structural layout of a building. (BuHamdan et al. 2021). This relates directly to the development of the housing typology in CH, as well as determining the initial construction approach, seeing as the base structure of the building must first be designed and built to enable the 'ongoing process' that the buildings are considered as in CH.

Envelope generation: The building envelope design heavily influences many sustainability metrics of a building's performance. GDSs offer valuable assistance in developing building envelopes that meet performance expectations by enabling the exploration and evaluation of numerous design options more efficiently and cost-effectively. (BuHamdan et al. 2021). This contributes to the goal of achieving innovative construction solutions, and energy-efficient designs contribute to the overall affordability of the building in the long run.

DISCUSSION

In the design of affordable housing, a standard quality of housing cannot be accurately established without the involvement of the end-users and considering their individual needs. The collaborative housing paradigm actively addresses this issue by involving the end-users in the design phase, creating housing projects where residents deliberately share spaces. (Brysch & Czischke 2022). Research has shown that, indeed, CH is more affordable and space-efficient than what is considered mainstream housing. (Brysch et al. 2023). The utilization of GDSs in the design exploration stage can assist in developing the multiple iterations necessary when responding to the requirements and needs of clients and regulations, results in the need to produce novel solutions. (Mukkavaara & Sandberg 2020). As the interest in applying GDSs in the architectural design field continues to increase (Mukkavaara & Sandberg 2020), this paper suggests a new application facet in taking advantage of the characteristics of GDSs to create affordable housing, specifically through the CH approach.

Florio and Tagliari (2021) used a parametric generative design system to develop new collective housing typologies to create culturally diverse spaces that are flexible and adaptable. The algorithm developed was based on parameters set by the architects, resulting in the successful creation of varied unit types. It, therefore, begs to reason that if the end-users needs and requirements consequently define the parameters, it will be possible to create affordable housing based on the most optimal design solution from the generated design iterations.

Software like '*PlanFinder*' exists and is being developed to generate plans based on prompts by the user within a specific space. This further shows how the application of generative systems can play a crucial part in CH and, thus, affordable housing design.

While using GDSs in the design process has clear upsides, producing these kinds of projects will require a new type of professional with modern skills who can design using algorithms (Florio & Tagliari 2021).

CONCLUSIONS

The demand for affordable housing remains an important issue that must be addressed globally. Many approaches can be taken to increase affordability in buildings. For the purposes of this paper, the emphasis was placed on the necessity of establishing a standard of quality housing through design. This paper is premised on the idea that the utilization of generative design systems during the design process of collaborative housing will facilitate the creation of design solutions that are inherently more affordable than mainstream housing.

This idea was explored by investigating the factors influencing affordability in collaborative housing design and relating them to the current applications of GDSs in today's industry, highlighting where these concepts intersect. The ability of GDSs to develop multiple iterations and find novel design solutions in response to the needs of the end-users makes it a practical and advantageous tool for the design of collaborative and, thus, affordable housing.

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