

L I V I N G ALGORITHMS

The Evolution of Housing Design
in the Age of Generative Design

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PROBLEM STATEMENT

The advancements in artificial intelligence are progressing rapidly, leading professionals, including architects, to question their future relevance. Meanwhile, many architects also admit that they have a heavy workload and often work long hours. While AI might seem like a threat, it also has significant potential to assist architects by handling various tasks, enabling them to focus on other responsibilities and work more efficiently (Amer, 2023). AI could help architects to retrieve and process data and turn it into information. By combining data interpretation and real-world experience, architects are able to create a deeper understanding and valuable knowledge of the unique challenges and opportunities that lie ahead, contributing to buildings that are not only functional but also sustainable and adaptable to changing conditions (Chew et al., 2024).

With generative AI software, architects can generate different design options, which is called generative design (Zhuang et al., 2023). Generative design could enhance creative thinking and address climate challenges to work to a better final design. By focusing on the opportunities generative design presents rather than the threats, the role of architects could evolve considerably in the future. This future will determine how a new generation of architects, today's architecture students, will practice their profession.

At the same time, architects should consider to what extent generative design can contribute to the architectural design process and face its limitations. Generative design, based on AI, might excel at the 'hard values' of architecture: economic and spatial efficiency. Think of designing efficient supporting structures, compact building forms, improved energy performance, and analyses of daylight, wind and noise.

However, this does not immediately make a building pleasant to live in, while this is a key aspect for residents, the users that have to deal with the consequences of the design work of the architect. This is where the 'soft values' of architecture come into play: well-being, beauty, social cohesion and respect for historical and cultural contexts. Think of a pleasant alternation of spaces and textures, the integration with nature, space for community spirit and preserving cultural historical heritage (TANGRAM Architekten, 2024). Human intelligence may still outperform artificial intelligence when it comes to these human values, which are crucial in housing design and making residents feel at home. Although the technical domain of generative design and the human domain of architects may seem at odds, they could possibly also complement each other. This research therefore aims to assess the role of generative design in the design process of dwellings, the homes of our future.

Research question:

What is the value of generative design in the architectural design process of housing design?

To assess the value of generative design within architecture, it must first be made clear which values architecture consists of, the foundations of good housing design. In general, within architecture, two types of values can be distinguished, which will be defined later:

Subquestions:

What are hard values within architecture?
What are soft values within architecture?

A drawback of this research is that it provides only a snapshot of the capabilities of generative design. Given the rapid advancements in generative design, and AI in general, and the significant investment

of time and resources, the findings could change dramatically in just a few months or years, making the research potentially outdated. However, it is still relevant to reassess the current state of generative design, consider its future implications, and explore how its capabilities can be applied in an architect's design process for dwellings. Architects, companies and architecture students can take advantage of this emerging trend by gaining knowledge and experience with generative design applications, positioning themselves to apply this knowledge more broadly in the future. Familiarity with generative design could offer a distinct advantage in one's career. However, the overarching aim of this whole research is to come up with a more informed approach to creating liveable spaces, which can lead to innovative solutions that enhance the quality of life for residents.

THEORETICAL FRAMEWORK

This research falls under the domain of computer-aided architectural design and dwelling architecture. It is about the relation between the digital possibilities and the practice of the architect designing homes.

It is essential to clearly outline and organize the architectural design process of a housing design project and link it to the use of generative design tools. When and how to use specific generative design applications and for what purposes?

Amer (2023) describes computational facilities which are the basis of AI and can assist architects during their design work. Amer (2023) goes through different phases of the architectural design process and shows different AI applications and techniques in each phase of the design process. Each architectural design process is unique, but in general a certain sequence of actions can be recognized. When this

phasing is linked to the use of AI, the following steps can be distinguished:

1. Data Management and Design Options
2. Building Information Modelling
3. Building Performance
4. Architectural Representation
5. Smart Construction

This phasing forms the basis for this research to explore the different possibilities of AI step by step. Amer (2023) concludes that AI applications would not substitute the architects or replace duties in design and planning, but they could serve as powerful tools to assist architects in getting a variety of design options using a lot of data in limited time.

Generative design

AI comes in different forms, but this research will be focused on the use of generative design. Generative design is a design process in which different types of generative AI software help generate different design options. Generative design simulates the physical world and quickly comes up with suggestions (Zhuang et al., 2023). In this case, it is no longer a matter of artificial intelligence assisting humans in designing, but of humans lending a helping hand to artificial intelligence in designing, a kind of 'human-assisted AI design'. Architects can feed the design software with all kinds of parameters such as performance requirements, spatial limitations, use of certain materials, production methods and more. The generative AI software generates many different designs with corresponding alternatives based on this. Integrating this advanced technology could force a quicker and more effective response to design methodologies, leading to enhanced innovation and sustainability in the architectural design process, possibly also in housing design (Chew et al., 2024). Generative design tools therefore have the

potential to design a more sustainable, resilient, and inclusive built environment for future generations (Chew et al., 2024). For this research, in which various generative design tools are tested against the design process of dwellings, it is important to get an overview of promising available tools and link them to the five different phases:

1. Data Management and Design Options

Grasshopper

Ark Design AI

Maket

2. Building Information Modelling

Architectures

BricsCAD

3. Building Performance

Autodesk Forma

Cove.tool

4. Architectural Representation

DALL E

Veras

5. Smart Construction

Ark Design AI

Autodesk Forma

Values of architecture

A key focus of this research is how AI, and more specifically generative design, addresses the soft values of architecture. TANGRAM Architekten currently presents an exhibition on this theme, in collaboration with TU Delft and others, titled “Immeasurably Important - AI and the Soft Values of Architecture.” The exhibition argues that AI excels at addressing the hard values of architecture:

- economic efficiency
- spatial efficiency

However, the central question in this exhibition is how AI can be used to create deeply human-centered, emotional and sustainably responsible architecture, aiming at the soft values of architecture. These soft values play a crucial role in

making residents feel content and at home (TANGRAM Architekten, 2024):

- well-being
- beauty
- social cohesion
- respect for historical and cultural contexts

Research and design

The use of generative design in the architectural design process is about the interaction between research and design. The interaction between research and design can be distinguished in 3 forms (Findeli, 2004):

- “Research for design” focuses on assisting, guiding, and advancing design practices and documents the processes and challenges faced by professional designers, considering both the designers and their practice as the subject of study.
- “Research into design” focuses on documenting objects, phenomena, and the historical context of design.
- “Research through design” focuses on insights gained through the design process itself and is concerned with the end product of the design..

METHODS

The design and research methods that will be used include literature and media study, conducting interviews, case study analysis and testing generative design tools.

To understand the definition and current landscape of generative design, identify existing generative design tools and how these generative design tools can be applied, a study of literature and media is conducted.

The connection between research and design can be categorized into three types:

research for design, research into design, and research through design. All three domains are part of the methodology of this research.

Conducting interviews

Interviewing architects who use generative design in the architectural design process falls under the domain of “research for design”. Interviews with architects will help to understand how generative design is currently being used in architecture firms, what challenges they face, their perspectives on generative design’s potential and how generative design could possibly improve housing design from their point of view. Architecture firms that are already involved in generative design or AI in general and therefore may be interesting to interview:

- AFRY used generative design tools to mitigate flood risks, reduce environmental risks and to find an effective way to evaluate multiple design iterations and layouts early on.
- Mecanoo uses AI as a sketchbook and library of ideas.
- TANGRAM Architekten organises an exhibition on AI and the soft values of architecture. AI might be able to design very efficient buildings, but a building designed by AI is not yet a pleasant place to live, according to this architectural firm.
- MVRDV explores the use of AI and different generative design tools in the architectural design process and has already used generative design in the design process of the Valley in Amsterdam.

Case study analysis

Case study analysis falls under the domain of “research into design” and is linked to conducting interviews. A select few case studies, preferably designed by the

architects interviewed, such as the Valley designed by MVRDV, will be chosen for analysis. The case study analysis must clarify how generative design tools have been used in a specific completed project and examine to what extent the soft, human values of architecture have remained intact, despite, or perhaps because of, the use of generative design tools.

Testing

The insights gained from the literature and media study, conducting interviews and case study analysis are ultimately put to the test through practical application by testing out different generative design tools. The individual design process for a residential graduation project will serve as a framework to provide insights on the use of different generative design tools in different phases of the architectural design process, which falls under the domain of “research through design”. This architectural design process is divided into five phases, with two generative design tools being tested in each phase, as stated in the theoretical framework.

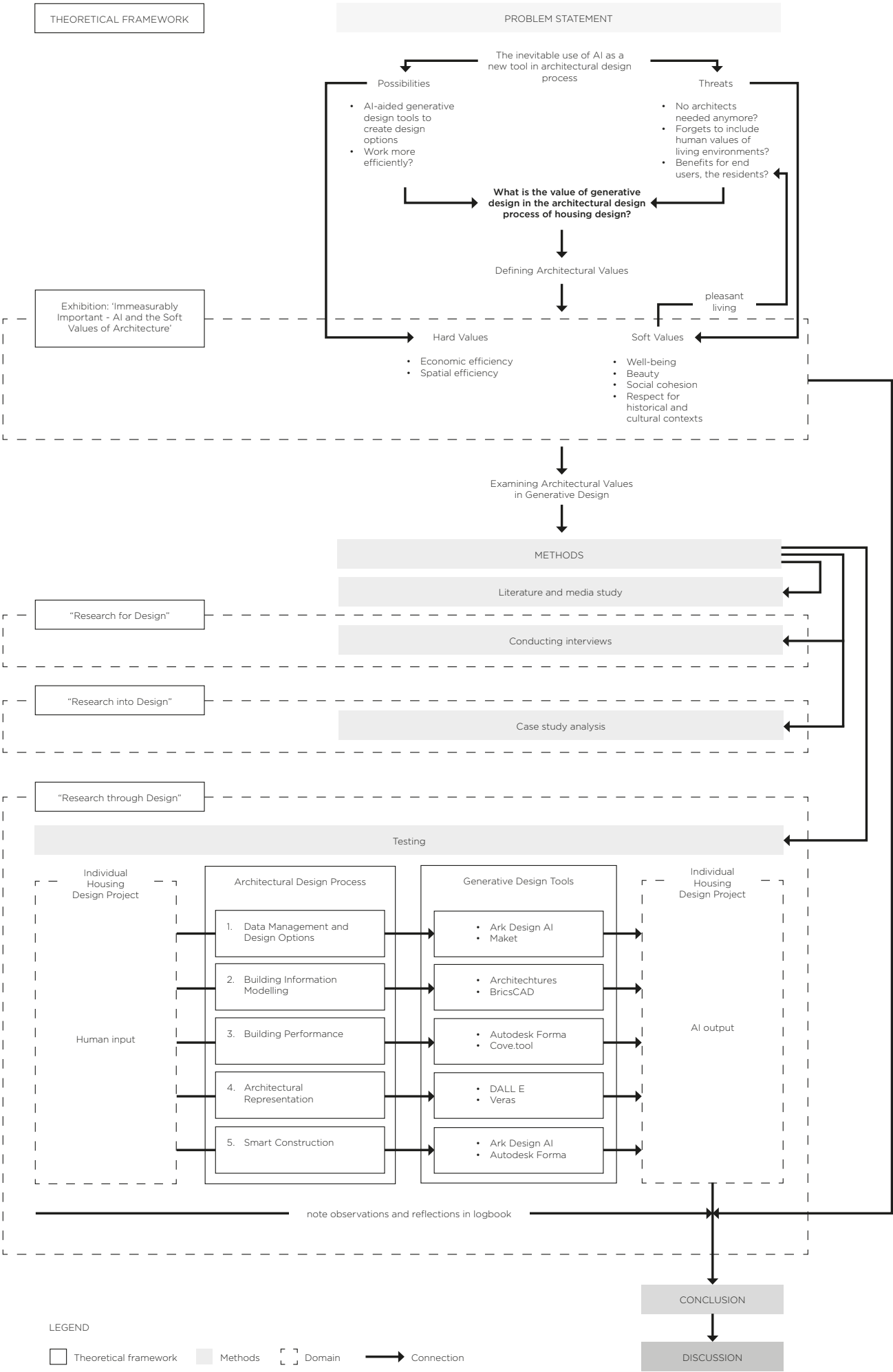
When testing these (multipurpose) generative design tools, careful observation is crucial. The input for these tools is based on an individual’s subjective thought process, informed by a specific architectural housing design assignment within a particular context. For instance fluctuating water levels, a noteworthy design aspect in the individual design project, could potentially influence the design input used for generative design tools. Information about water might provide context to the generative design tools. To help ensure objectivity during testing, all thought processes and observations are documented and reflected upon. This results in a detailed logbook that is valuable not only for the individual housing project but also for other housing design projects

in different contexts. Other architects, architecture students or designers in general must be able to understand how the input for the generative design tools was generated and be able to review the entire architectural design process for their own design project.

After identifying the values of architecture that are addressed at each of the five phases in the architectural design process, a distinction will be made between hard and soft values. The tools used must then clarify how generative design has dealt with these values. How effective is a generative design tool in securing the hard and soft values of architecture? To what extent are the human skills of the architect needed?

Testing generative design tools will hopefully lead to broader conclusions about AI's role in the architectural design process. This may include but is not limited to optimizing dwelling layouts, improving material efficiency to reduce CO2 emissions, enhancing the residential community feeling, implementing climate related challenges and preserving cultural historical values. The initial findings from this research are likely to shed light on specific AI-aided digital generative design tools and methods currently available for use in an architectural design process. The conclusion of the research will reflect upon how generative design tools treat the hard and soft values of architecture to examine the value of these tools. By assessing the value of generative design tools in the architectural design process, this research should be able to provide clarity on how a more technically informed approach to housing design could possibly end up in creating better living environments for residents.

RESEARCH DIAGRAM



BIBLIOGRAPHY

Amer, N. (2023). Architectural Design in The Light of AI Concepts and Applications. *MSA Engineering Journal*, 2(2), 628–646. <https://doi.org/10.21608/msaeng.2023.291906>

This article helps getting familiar with recent computational AI techniques and software, such as GANs and BricsCAD.

As, I., & Basu, P. (2021). The Routledge Companion to Artificial Intelligence in Architecture. In *Routledge eBooks*. Routledge. <https://doi.org/10.4324/9780367824259>

This book explores the possibilities in the field of AI related to architecture and discusses both theoretical and practical methods and techniques. It also provides a glimpse into the future of AI. Since this book is published in 2021, some of the methods, tools and techniques mentioned may have evolved further in recent years, which may be worth re-evaluating.

Bianco, L. (2018). Architecture, values and perception: Between rhetoric and reality. *Frontiers Of Architectural Research*, 7(1), 92–99. <https://doi.org/10.1016/j.foar.2017.11.003>

Bianco discussed various architectural design values and their respective intentions, which could provide possible depth to the hard and soft values mentioned in the exhibition “Immeasurably Importance - AI and the Soft Values of Architecture”.

Chew, Z. X., Wong, J. Y., Tang, Y. H., Yip, C. C., & Maul, T. (2024). Generative Design in the Built Environment. *Automation in Construction*, 166, 105638. <https://doi.org/10.1016/j.autcon.2024.105638>

This paper investigates the use of generative design within built environment, sustainability, BIM and AI design practices, clarifying its potential to create a more sustainable, resilient, and inclusive built environment for future generations.

Findeli, A. (2004). *La recherche-projet: une méthode pour la recherche en design*. Paper presented at the Symposium de recherche sur le design, Bâle, Suisse. Alain Findeli elaborates in his paper on the connection between research and design and distinguishes 3 forms of design research: research for design, research into design and research through design.

Huang, J., Johanes, M., Kim, F. C., Doumptioti, C., & Holz, G. (2021). On GANs, NLP and Architecture: Combining Human and Machine Intelligences for the Generation and Evaluation of Meaningful Designs. *Technology/Architecture + Design*, 5(2), 207–224. <https://doi.org/10.1080/24751448.2021.1967060>

This paper investigates how human and artificial intelligences can work together to generate new designs that are meaningful in a cultural and architectural way. It mainly focuses on the use of Generative Adversarial Networks (GANs), which might be meaningful in the first stages of design.

Ko, J., Ajibefun, J., & Yan, W. (2023). Experiments on Generative AI-Powered Parametric Modeling and BIM for Architectural Design. *arXiv (Cornell University)*. <https://doi.org/10.48550/arxiv.2308.00227>

This paper introduces generative design in 3D architectural design, extending beyond the use in text and generation of 2D images. It also promotes collaboration between the use of generative design tools and architects to come up with context-sensitive and creative designs.

Li, C., Zhang, T., Du, X., Zhang, Y., & Xie, H. (2024). Generative AI for Architectural Design: A Literature Review. *arXiv (Cornell University)*. <https://doi.org/10.48550/arxiv.2404.01335>

This article links the use of different generative AI models to different steps in the architectural design process.

TANGRAM Architekten. (2024). *Onmetelijk belangrijk Tentoonstelling - TANGRAM Architekten*. <https://tangramarchitekten.nl/en/project/onmetelijk-belangrijk-tentoonstelling-2/>

TANGRAM Architekten organises an exhibition on AI and the soft values of vrchitecture. The central question in this exhibition is how AI can be used to create deeply human-centered, emotional and sustainably responsible architecture, aiming at the soft values of architecture: well-being, beauty, social cohesion, and respect for historical and cultural contexts.

Zhuang, X., Ju, Y., Yang, A., & Caldas, N. L. (2023). Synthesis and generation for 3D architecture volume with generative modeling. *International Journal Of Architectural Computing*, 21(2), 297–314. <https://doi.org/10.1177/14780771231168233>

This paper defines generative design and shows how generative design is capable of uncovering patterns and generating solutions for complex problems that are not always apparent to human designers.

