



Artificial Intelligence Applied On Today's Urban and Architectural Conceptual Design - A Competition Case Study

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Abstract

The rapid advancement of Artificial Intelligence (AI) has introduced new possibilities in urban and architectural conceptual design, reshaping traditional workflows and creative methodologies. This thesis starts by literature review and case studies to set a theoretical background. After that it investigates the application of some mature AI tools, including ChatGPT, DALL·E, and Stable Diffusion as examples, within the context of a design competition, which focused on urban and architectural issues. This thesis studies how AI can support conceptual design. It focuses on how AI may change the traditional design process in urban and architectural projects. Meanwhile, it also examines the limits of current AI tools.

The thesis focuses on a project turning vacant high-rise office buildings into residential houses. It looks at urban challenges in Shanghai's Pudong district. It starts by analyzing the lifestyles and social issues of the user- young professional couples, till the design concept decision made. It shows how AI can help to create and improve ideas in the design process.

The findings show that AI is a useful tool in conceptual design. It speeds up the process and helps generate ideas. However, human expertise is still needed for spatial and contextual decisions, also traditional tools. There is a possibility to create a better workflow.

Key-words: Artificial Intelligence, Conceptual Design Process, Architectural Design, Urban Design, ChatGPT, Stable Diffusion

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Introduction

Problem Definition

In recent years, AI technology has experienced an explosive surge in development, with its application in architecture and urban design practices becoming an unstoppable trend, while lack of enough research, especially on how it influences the entire conceptual design process.

This explosion in AI has given rise to several new research questions:

-AI technology has developed so rapidly, but what is the current state of its **practical application** in the fields of **architecture and urban design**?

-What are the key processes of one design practice, and how AI applied on this?

-How does AI technology **impact traditional design process**, how to consider during its use?

Methodology

This research primarily utilizes a **case study** to investigate how AI tools are integrated into a conceptual design in a competition project, focusing on their role in different steps of the design workflow and their potential to transform the traditional design processes.

The case study is conducted from urban research to architectural design, providing a detailed analysis of AI's impact in each step of conceptual design process. In parallel, a **literature review** helps to identify the most mature AI tools applied currently, to provide a background.

The study concludes with a new workflow, which demonstrates the potential changes AI could bring to the traditional design practices, including the challenges of current AI tools.

All research, design, and analysis were conducted by the author, with AI and translation tools used only for grammar refinement, do not affect originality and academic integrity.

Thesis Purpose

This thesis focuses on the conceptual design phase of architecture and urban design, and investigates how designers use AI technologies in design to understand the current application. A design competition is used as a case study. It tests AI technologies such as ChatGPT, DALL-E, and Stable Diffusion in it. The thesis aims to show how these tools affect traditional design workflows and the possibility of creating a better workflow.

The research looks at both what AI can and cannot do. It discusses how designers and students can use AI wisely and think critically when applying these tools in practice.

Chapter 01: Artificial Intelligence

Background

"Any sufficiently advanced technology is indistinguishable from magic."

– Arthur C. Clarke, British science fiction writer

1.1 AI History and Development

1.1.1 The Foundations and Early Development of AI

The term "artificial intelligence" (AI) is a controversial word, since its invention, with debates even in the exact time of its origin. In academic field, AI is commonly defined as "the ability of a system to correctly interpret external data, learn from this data, and use those learnings to achieve specific goals and tasks through flexible adaptation"(Haenlein et al, 2019) .

Discussions on AI in philosophy date back to ancient times. Materialists suggest that the mind can be understood in physical terms, forming the ground for an artificial mind. The debate over "whether machines can think" arises from the contrast, especially between dualism and materialism in defining the nature of the human mind (Wikipedia, 2024b). Jonathan Swift's *Gulliver's Travels* (1726), in which the King of Brobdingnag challenges the validity of mechanical reasoning, is one of the earliest examinations of machine intelligence. In 1942, Isaac Asimov presented the "Three Laws of Robotics", which shaped early ethical talks about AI till today, and influenced today's conversations about AI.

Interest in artificial intelligence was sparked in the 1940s, when Alan Turing, the founder of the Bombe machine in World- War 2, which deciphered the Enigma code. After that he developed the Turing Test in 1950: "If a machine can interact with humans without being identified as artificial, it is considered intelligent. ", setting the ground for AI.

At the Dartmouth Conference in 1956, the phrase "artificial intelligence" was named first. Early AI systems were able to learn languages and handle math problems. One of the earliest attempts to pass the Turing Test was MIT's ELIZA, which imitated talks in 1964.

There have been two significant ups and downs in AI development. Unmet expectations caused the first "AI winter" (1974–1980), which resulted in budget cuts and criticism. Nevertheless, research in commonsense thinking and logic programming progressed. AI recovered between 1980 and 1987, because of expert systems, and significant investments like Japan's Fifth-Generation project. However, these systems failed to interpret data and learn from human experience, exposing certain limits (Wikipedia, 2024b).

The second "AI winter" (1987–1993) happened due to economic crisis. Funding from businesses and governments decreased hugely. However, research about AI continued, especially **Machine learning**, which advanced during this time, and later became the base for many breakthroughs (Wikipedia, 2024b).

1.1.2 Modern Advancements and Challenges in AI

From 1993 to 2011, AI improved steadily and became applied in many areas.

It often worked behind the scenes. Better computing power, and continued research both speed up this progress. However, AI still could not reach human-level intelligence. As interest in AI faded, the field split into smaller areas. Many avoided calling their work "artificial intelligence." But AI technology also grew stronger in this period.

In the 21st century, AI gained more development. Big data and better computing made AI more powerful. Companies started greatly investing on AI. Around 2012, **deep learning** led to big breakthroughs. In 2017, the Transformer model pushed it even further. By the early 2020s, AI received huge investments (Wikipedia, 2024b). However, in the same time, its fast growth also raised concerns: risks, regulations, and future challenges.

Deep learning models high-level data abstractions through deep neural networks, excelling at complex problem-solving. While theoretically, single-layer networks can approximate any continuous function, deep networks are better suited for intricate tasks. Deep learning has surpassed human performance, in fields such as computer vision, handwriting recognition, and autonomous driving. A famous achievement was Google DeepMind's AlphaGo in 2016, which mastered the complex game of Go, marking a milestone in AI capabilities. Emerging data-driven AI technologies are starting to deeply influence design and other fields.

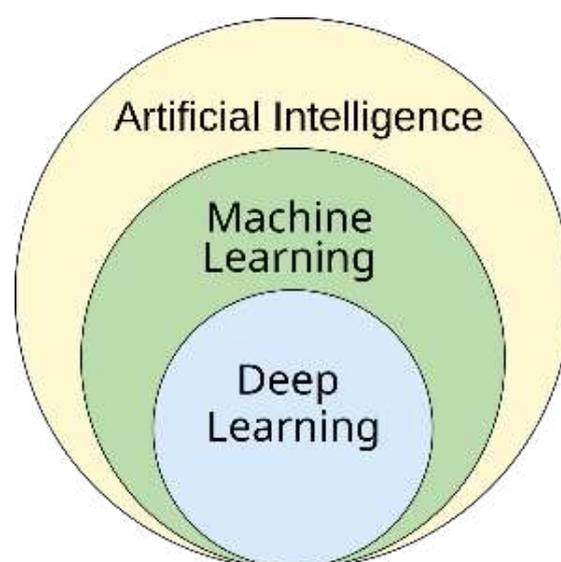


Fig. 1. AI hierarchy including deep learning.

Source: Wikipedia 2024. https://de.m.wikipedia.org/wiki/Wikipedia:WikiProjekt_KI_und_Wikipedia

1.2 AI Applied on Design Overview

Design, being a messy problem with shifting targets and trade-offs, relies on diverse knowledge, technical skills, and innovative ideas. Simultaneously, it is influenced by reality, including time constraints and the need for continued modifications. (Holmquist, 2017). Artificial intelligence is continually advancing, and can be used to help with the uncertainties and subjectivity in the design process. So not only does AI assist developers to remove themselves from rigid training paths of thought, but it also reduces reliance on existing human knowledge, providing designers with less biased suggestions.

Design has entered a new age of data-driven AI methods that have realized their potential for working with big data all while moving away from knowledge and experience-based design approaches. Traditional techniques like expert system and genetic algorithm are useful for knowledge-based design evaluation, and decision making. Machine learning, deep learning, and all the other modern technologies that we got from computing and big data are great at creating ideas, generating concepts, and generating 3D models. (Yüksel et al., 2023).

In recent years, deep learning has surpassed human abilities in areas such as language recognition, image recognition, and strategic games. In 2012, breakthroughs in image classification marked the rise of deep learning, which later expanded to more complex tasks like image generation and description. By 2015, new techniques overcame the challenges of training deep networks, greatly improving model performance, and influencing artistic creation, as seen in Google Deep Dream and neural style transfer. By the early 2020s, generative AI tools like ChatGPT, Mid-journey, and DALL-E became popular. They created text, images, and videos with high realism and ease of use. Their popularity kept growing.

AI is thus significantly reshaping the design industry. "Designers need to educate themselves and adapt to these new tools, to handle the major transformations in future product development" (Holmquist, 2017). In the age of AI, the role of designers is shifting from developing complete solutions, to identifying innovative problems, creating frameworks, and setting up software, data infrastructure, and iterative mechanisms to enable real-time AI evolution (Dixon et al., 1984). AI methods can fully or partially support design and assist designers in completing tasks at various decision-making stages (Fu and Zhou 2020). While AI-generated ideas and concepts may not always be ideal, human intervention can gradually bring them closer to the desired levels (Liao et al., 2020).

There are obvious limitations to AI in design. Algorithms struggle to adjust to change and lack human intuition. They also depend on high-performance computation and vast amounts of data. The "black box" issue plagues many AI systems, making it difficult to explain their response, even for the researcher. AI is unable to perform difficult creative activities on its own, according to research. In terms of originality, interpretation, and abstract thought, it still lags behind human designers. (Yüksel et al., 2023).

Nevertheless, AI is gradually becoming a core driving force in the design field. Particularly in the conceptual design, its powerful data processing and creative capabilities, provide important support for improve traditional design workflow, and enhancing creativity. Designers must embrace this new technology and design methods, even it is so new, while addressing its limitations in interpretability and adaptability, also, the potential ethical challenges. However, through human-AI collaboration, the strengths of both can be improved to enhance the design to a new era.

Chapter 02: Today's AI Application in Urban and Architectural Design

2.1 How International design firms use AI tools

AI has been part of urban and architectural design for years. Its role has grown, leading to more diverse uses. Leading design firms show that AI improves efficiency, sparks creativity, and drives innovation.

Foster + Partners, a major design firm in London with over 1,400 employees, uses AI to enhance creativity and problem-solving. Its Applied R+D department developed Hydra, a tool that generates urban design options and performance analyses in hours. These results help train AI to suggest better designs for new projects. The firm also created a knowledge database with millions of documents. Designers can search texts, drawings, and models using natural language, making work faster and more efficient.

The company integrated Stable Diffusion into design tools like Rhino. Designers can generate ideas from text prompts while keeping intellectual property secure. In material science, AI predicts how materials react to temperature changes and improve layered material designs (Foster + Partners, 2025). This shows how large firms use AI to improve efficiency and innovation.



Urban Scale Simulations

For the biggest project of **2.17M** GFA, Hydra has generated more than **18,000** variants running over **80,000** simulations over 3 design sprints.



Area Green Views Pedestrian VSC



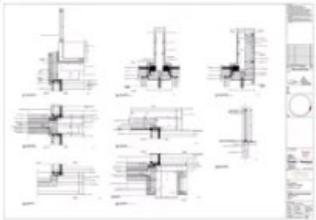
(a)

F+P Search

BETA

Cladding Systems, Middle East, Schematic Design

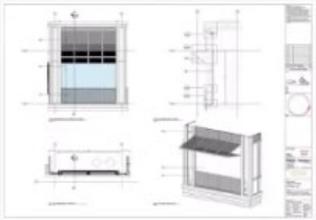
Results (21)



Cladding & External Wall Systems
- Typical Details

Project: Laheq Island
AOR: Dewan Architects

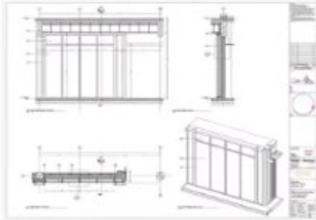
MORE



Cladding & External Wall Systems
- Folding Door System Details

Project: Laheq Island
AOR: Dewan Architects

MORE



Cladding & External Wall Systems
- Timber Panels Details

Project: Laheq Island
AOR: Dewan Architects

MORE

(b)

Fig. 2 The internally developed tool, Hydra, generates thousands of urban design solutions and their performance (a). AI-powered search inside Foster + Partners that includes design and details (b).

Source: https://www.aecbytes.com/newsletter/2024/issue_130.html

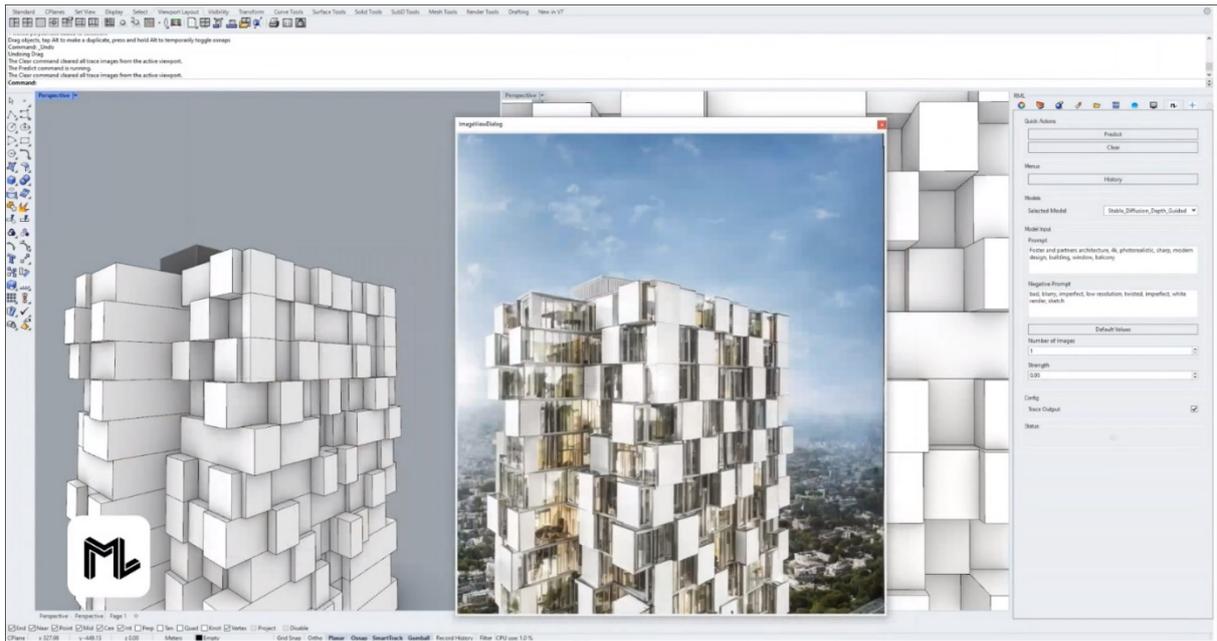
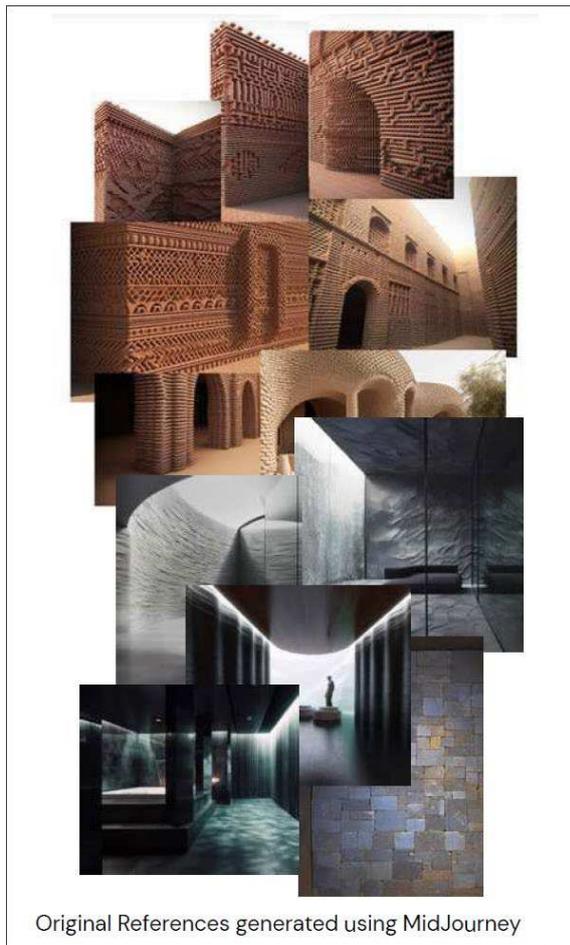


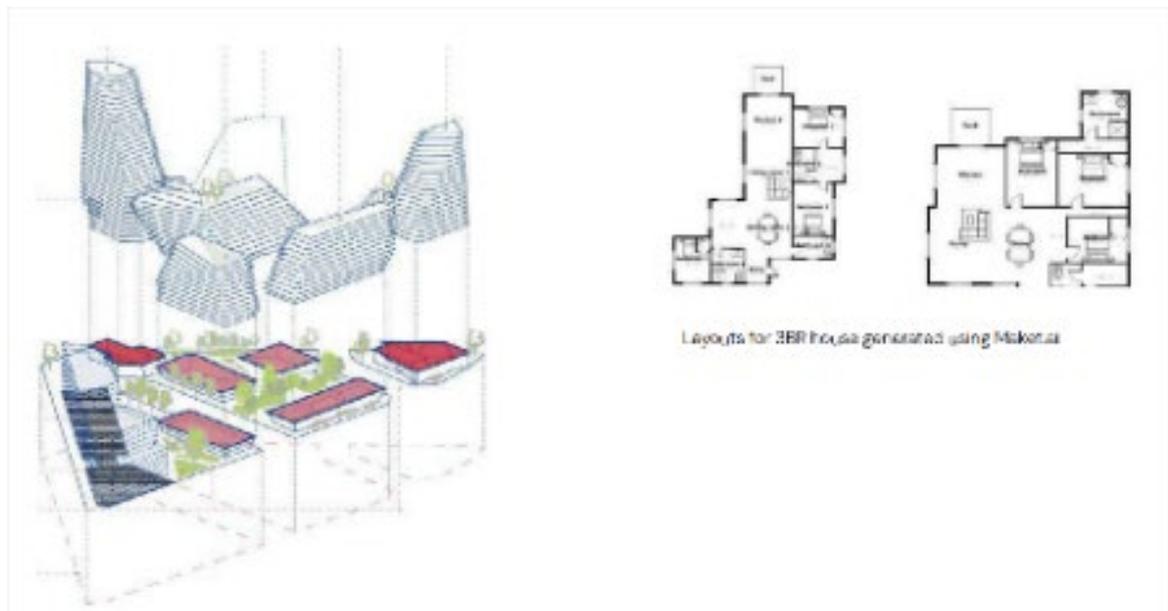
Fig. 3 An in-house Stable Diffusion on depth-guided model integrate in Rhino. *Source: <https://www.fosterandpartners.com/insights/plus-journal/design-technology-and-the-team-between>*

Smaller and medium-sized firms use AI in different ways. The design company **NAME**, known for cultural and residential projects, applies AI in conceptual design, planning, visualization, and client communication. For example, they use Midjourney to create design references, and train models with Krea.ai to match their studio's style. For planning, they rely on Autodesk Forma for site and layout analysis. In visualization, they test various tools to speed up rendering and animation. (Khemlani 2024).

Other innovative small-to-medium firms enhance creativity and efficiency by customizing AI tools. Heatherwick Studio, for instance, trains AI on 30 years of design archives to produce matching results. (Khemlani 2024).



(a)



(b)

Fig. 4. In NAME Architecture, AI tools like Midjourney generate unique references to explore materials, lighting, and atmosphere (a). Planfinder.ai and Maket.ai for generating layout options for planning projects (b). *Source: https://www.aecbytes.com/newsletter/2024/issue_130.html*



Fig. 5. In Heatherwick Studio, the design from the company’s 30 years archives were used to train the AI. Source: https://www.aecbytes.com/newsletter/2024/issue_130.html

Some top global tech companies, including Alibaba, are actively using AI to support smart city development. For example, Alibaba’s *City Brain* system processes large amounts of data on traffic, energy, and the environment in real-time to improve resource management and urban planning. In addition, organizations like the United Nations Human Settlements Programme (UN-Habitat) work with tech firms in China, to develop new smart city models that address urbanization challenges. These efforts highlight AI’s strong potential in shaping the future of smart cities (UN-Habitat 2019).

2.2 Today's AI applied in Urban Design Field

Urban design is more complex than architecture and other design fields. It involves multiple factors that keep changing (Goodchild 2010), and divides urban design into two main types:

General Urban Design (Big-D "Design"): focuses on the full design process. It starts with identifying problems and moves toward solutions. It deals with complex challenges, involves many stakeholders, and requires continuous adjustments.

Narrow Urban Design (Small-D "design"): solves specific tasks within a structured design space. It prioritizes efficiency and precision in generating solutions.(Goodchild 2010).

However, " both of them have advantages and limitations in supporting complex urban sustainable design issues with design, science, and computation"(Goodchild 2010).

These two schools of thought still possess the previously stated fundamental shortcomings. However, the development of artificial intelligence has significantly enhanced the capabilities of planning and design, support systems for both (Quan et al. 2019).

With better computing power, more data, and easier access, AI is shaping urban design. How does it influence these two areas? How does it help manage resources, coordinate stakeholders, and create data-driven, sustainable plans? What new applications have emerged?

2.2.1 AI applied in General Urban Design

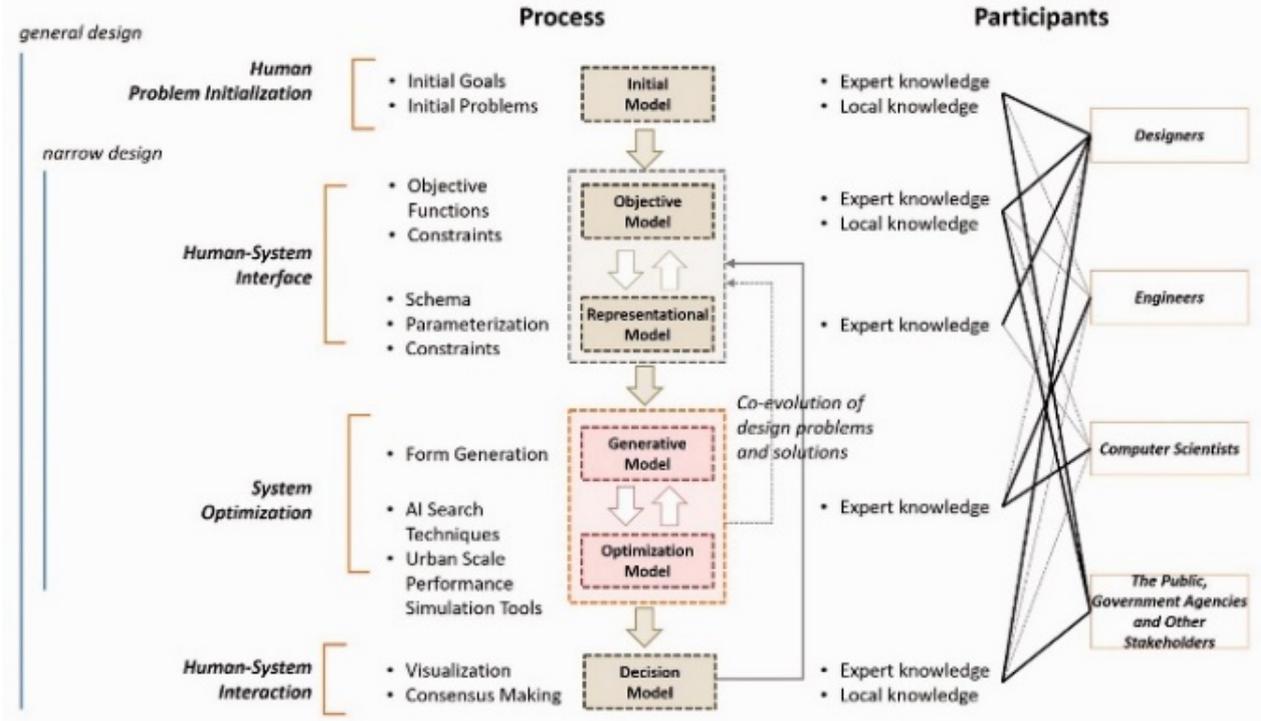
Scientific Urban Design framework

Artificial intelligence has made progress in automating design tasks. However, a major challenge remains: how to integrate stakeholder knowledge and needs into a structured design process. Ensuring the co-evolution of design problems and solutions is difficult due to the vast amount of design knowledge, the complexity of design thinking, and the challenge of automating stakeholder involvement (Batty 2018; Quan et al. 2019).

AI alone cannot solve urban design problems. But smarter human-AI systems can improve large-scale design efficiency. A structured process can help AI analyze urban issues and support decisions. The "**intelligent design framework**" has four stages: problem initialization, interface development, system optimization, and interactive collaboration. (Quan et al. 2019). This approach combines scientific models with AI-driven methods to explore the best solutions for sustainable development (Quan et al. 2019).

A case study of the Gangnam Superblock in Seoul shows how this framework works. Through two iterations, it optimized design solutions, achieving the lowest energy use intensity and the highest floor area ratio. This provided a strong basis for further decisions(Quan et al. 2019).

The framework integrates design, science, and AI, using structured representation, simulation tools, and genetic algorithms to support intelligent design choices as goals evolve.



(a)

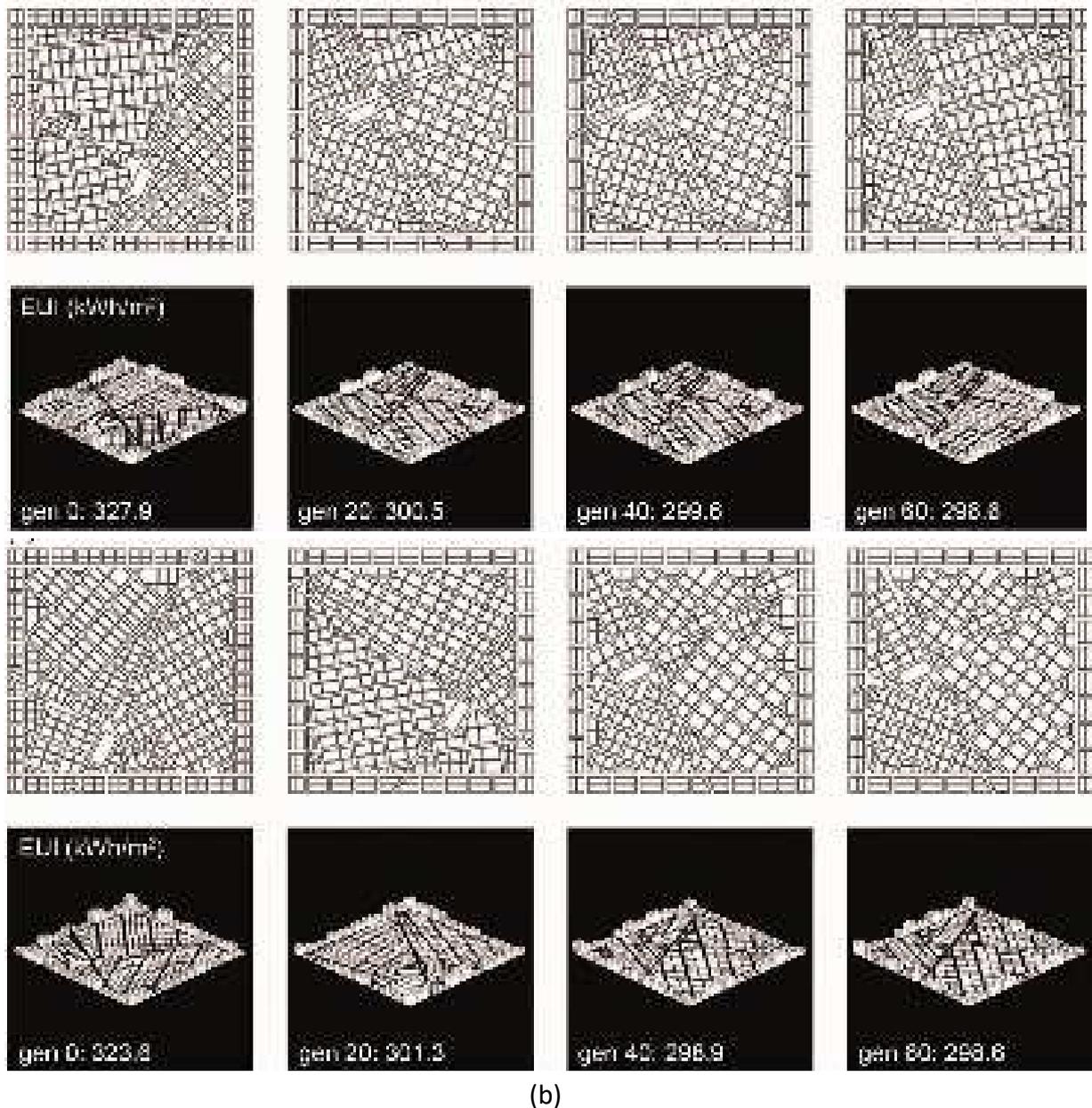


Fig. 6. The Smart Design framework (a). Two sets of plans and axonometric projections illustrate the optimization process at generations 0, 20, 40, and 60 for the first run and the second run. **EUJ:** Energy Use Intensity; **Gen:** Generation. (b). *Source: Quan et al. 2019.*

<https://journals.sagepub.com/doi/abs/10.1177/2399808319867946?journalCode=epbb>

This framework still needs improvement in areas like design updates, multi-objective optimization, and uncertainty management. Its real-world application also requires more testing. However, it offers valuable insights into AI's role in urban and design fields. Instead of waiting for AI to advance, the focus should be on developing smarter human-AI interaction systems. Improving decision-making is a key focus for future urban design research.

As AI advances and design knowledge grows, its role in urban planning will expand. Soon, AI could provide more innovative solutions, helping build smarter and more sustainable cities.

Urban Data Integration and Decision Optimization

AI and other data-driven technologies are shaping the next generation of GIS systems by creating frameworks that link multiple data sources (Zaluska, 2021). AI plays a key role in urban data creation and visualization, using computer vision and deep learning to build highly detailed urban models, and support intelligent design platforms. AI enhances urban planning by analyzing complex regulations, processing economic data, and generating layouts quickly. With generative design and multi-objective optimization, it evaluates legal compliance, financial feasibility, and environmental impact. These tools support planners, designers, governments, and developers, improving efficiency and decision-making accuracy.

AI improves urban modeling by enhancing data quality and automating processes. When importing GIS data, AI uses deep learning to correct errors and fill gaps, increasing accuracy. It also combines drone images and LiDAR data to detect buildings, roads, and bridges. This creates precise and detailed 3D models with high efficiency.

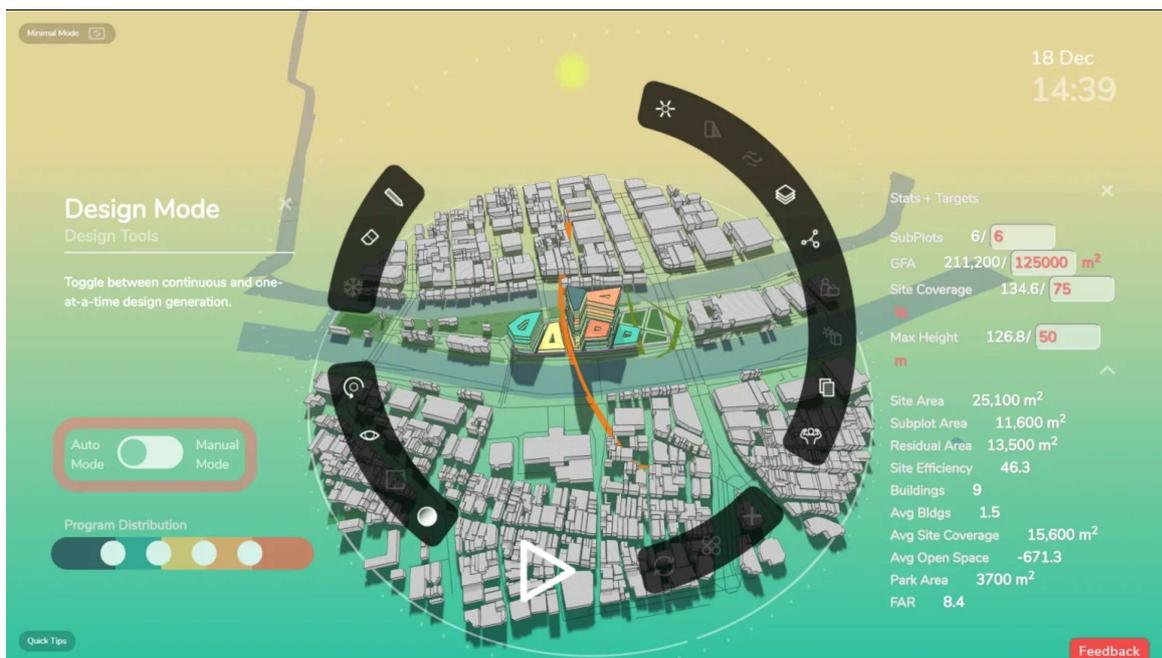
AI helps decision-making in complex projects by integrating data and optimizing solutions. The DBF (Digital Blue Foam) platform streamlines the design process from concept to final delivery. It applies AI-driven spatial analysis and computational optimization to "cut costs by 15% and reduce design time by 50%. (DBF, 2024)"



Urban Diagnostic Engine with Generative AI



(a)



(b)

Fig. 7. DBF platform integrates geospatial analysis, and open data to provide personalized urban insights, supporting decision-making and enhancing accessibility (a). A user-friendly interface that ensures a smooth interaction experience of the DBF platform (b).

Source: <https://www.digitalbluefoam.com/whitepapers/dbf-citypulse-generative-planning-for-what-if-urban-diagnostics-and-scenarios>

AI provides developers and decision-makers with advanced tools for urban design. It uses natural language processing to analyze regulations and generative design to create optimized layouts and development plans. AI also balances design, costs, revenues, and legal requirements. Machine learning predicts financial feasibility.

DeepBlocks applies AI to real estate development and urban planning. It enables quick site selection and feasibility assessments. Developers use it to find ideal locations across cities (Deepblocks 2024). These platforms improve collaboration and stakeholder involvement.



Fig. 8. DeepBlocks help developers to filter and analyze hundreds of thousands of sites in minutes.

Source: <https://deepblocks.com/>

Public Participation in Urban Design

The public are the true users of cities. However, traditional urban design processes struggle to empower the public to directly generate design proposals. This limitation hinders the highest level of design empowerment under the "public design" concept—enabling citizens to independently create their own designs, and take control of the future development of cities that closely affect their lives (Quan 2022).

AI improves public participation platforms, creating new ways to address this challenge.

UrbanistAI, which is a map-based civic engagement platform, combines urban data with image generation. It makes urban design information easier to understand for people not professional, helping the public engage in design decisions (UrbanistAI 2023). AI also processes public feedback and creates visual reports for policymakers. This improves transparency and public involvement.

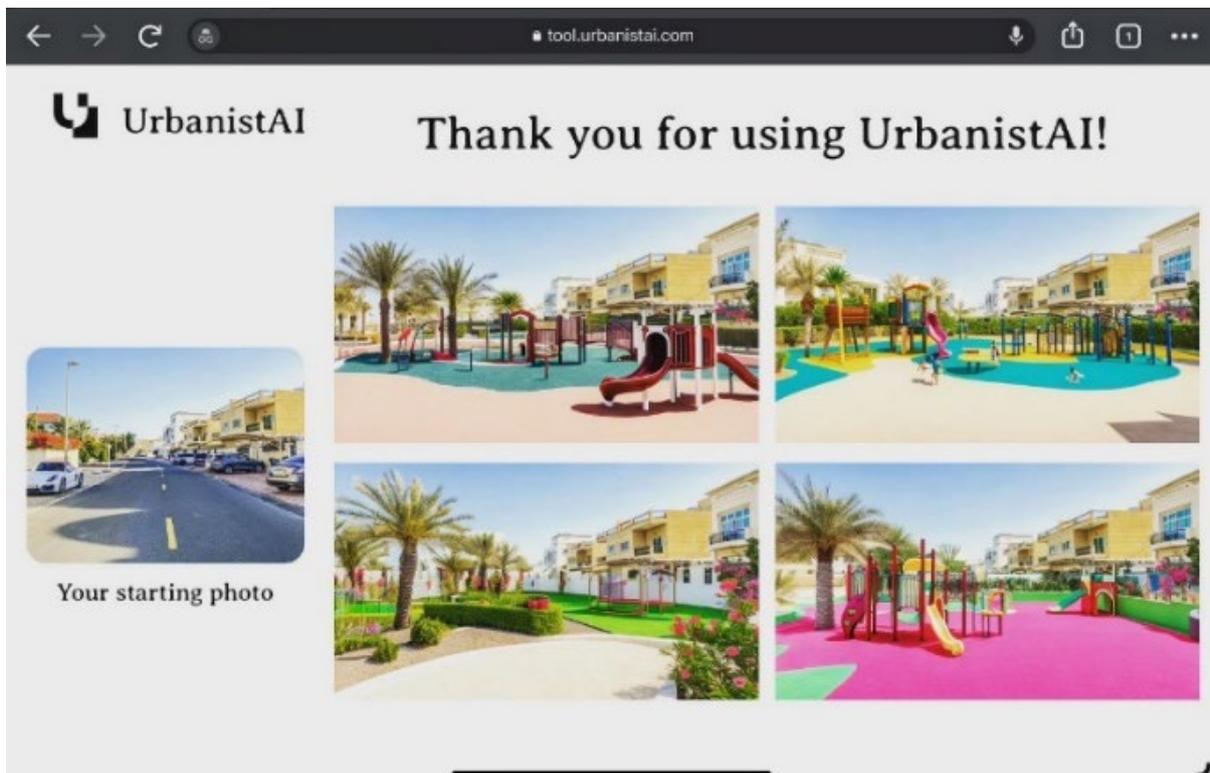


Fig. 9. The user-friendly website interface of Urbanist AI to enhances the citizen participation.

Source: <https://site.urbanistai.com/>

Urban-GAN is another example. This system integrates DCNN, CBR, and GAN technologies to generate diverse urban design solutions. It lowers technical barriers and allows more people to take part in the design process. By learning from urban forms in cities like Manhattan, Portland, and Shanghai, it generates diverse design proposals. Experiments show that even non-designers can create visually and functionally structured designs (Quan 2022). Urban-

GAN simplifies processes and enables personalized design, deepening and enhancing public participation.

Though still in the early stages, these systems highlight AI's significant potential in enabling public participation in design. In the future, as functionalities expand and applications diversify, AI is expected to further empower the public in urban design, promoting more inclusive and innovative design approaches.

2.2.2 Today's AI applied in Narrow Urban Design

Rapid Generation of Sustainable Design Solutions

AI has made strong progress in narrow urban design, especially in **Generative Urban Design (GUD)**. GUD uses artificial intelligence and computational methods to improve efficiency in the early design stages. It plays a key role in enhancing traditional design workflows (Jiang et al. 2024).

GUD applies to both single-element designs, like streets and buildings, and multi-element designs, like street-lot-building integration. Instead of optimizing for one goal, it balances multiple objectives to support urban sustainability (Lobaccaro and Frontini 2014).

Human designers are not replaced by GUD. Rather, it alters their function. Rapid prototyping is made possible, which changes the emphasis from "design-centric" to "decision-centric." Designers focus on establishing guidelines and making wise decisions. (Jiang et al. 2024).

Advancing AI has led to efficient urban design tools used in real projects. One example is Delve, a generative design tool from Sidewalk Labs. It applies machine learning to generate millions of design options in minutes. This speeds up planning, improves project viability, and enhances residents' quality of life (Delve, 2020).

In the **Wembley Park** project in London, the developer Quintain utilized the Delve tool to quickly generate and evaluate over 40,000 design schemes (Quintain, 2020). The process resulted in 24 high-performance options, increasing housing density while improving sunlight access and open spaces.

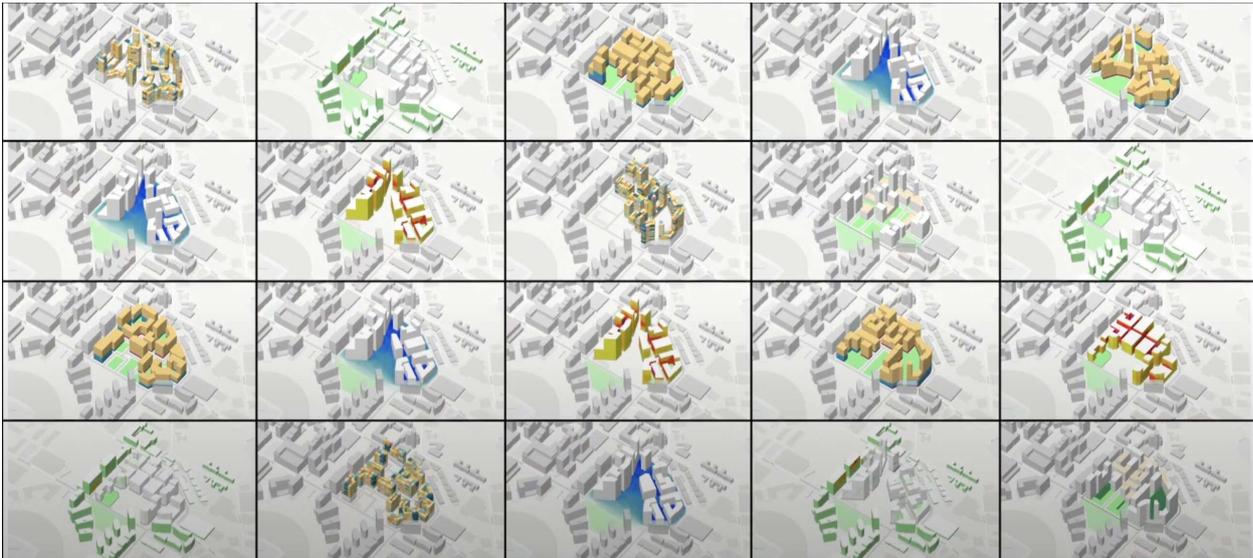


Fig. 10. Some urban design options of the AI-generated design in the Wembley Park project.

Source: https://www.aecplustech.com/projects/wembley-park?utm_source=chatgpt.com.

Foster + Partners' R+D technology department has developed **Hydra**, an urban design software designed as an internal cloud platform to accelerate computation and performance-driven design. Since its launch in 2019, Hydra has generated over 240,000 design options and conducted more than 1.3 million performance simulations, during the conceptual design phase. By using AI, Hydra quickly generates and analyzes many design options. It evaluates performance factors like massing views, sunlight potential, and solar radiation. This improves design efficiency and helps create better solutions (Kosicki, Tsiliakos, and Tsigkari 2020).

Hydra's success in real-world projects further proves its potential for generating and improving design solutions. For example, in the **Shenzhen Guangming Hub Masterplan** project in China, Hydra created and analyzed over 10,000 design options to find the best building layouts and performance solutions. This award-winning transit-oriented development along China's high-speed rail network needed to meet site-specific requirements, while improving environmental performance, reducing walking distances, and increasing green spaces. By using design rules and project needs, Hydra automated the process of creating and evaluating thousands of options, helping the design team find high-performance solutions while greatly reducing manual work (Foster + Partners, 2025).



Fig. 11. The Guangming Hub Masterplan project used Hydra, located in Shenzhen, China.

Source: <https://www.fosterandpartners.com/insights/plus-journal/design-technology-and-the-team-between>

Additionally, China's **XKool** uses its proprietary AI design engine and intelligent cloud platform for projects in cities like Yantai, Changchun, and Xi'an. By applying parametric models, XKool explores multiple design possibilities and provides solutions, that exceed traditional standards (Jiang et al. 2024).

In **affordable housing** planning, AI also shows great potential. Cityplain, a cloud-based urban planning tool, improves urban expansion designs with artificial intelligence. The platform delivers results from comprehensive scenario analyses in minutes instead of months, allowing for detailed comparisons and seamless collaboration across teams. This capability supports efficient planning and development, for rapidly growing residential areas, helping fast-developing cities meet urgent housing needs.

Enhancing Implementation and Interdisciplinary Collaboration

Urban design covers many urban issues and integrates large amounts of information. However, in practice, it can lack of continuity. AI helps this by generating design quickly and improving collaboration across different phases. It connects urban data with other information like BIM models, ensuring a much smoother workflow. It also links urban, architectural, and landscape design, creating a more cohesive process.

Among AI-powered design platforms, **Spacemaker** by Autodesk is a leading example. It speeds up urban planning and improves sustainability with advanced AI technology. Its user-friendly interface allows users to generate, optimize, and refine designs, even without experience in design software.

As a generative design tool, Spacemaker integrates with Autodesk's BIM tool, Revit. This allows conceptual designs to transition smoothly into BIM models, ensuring an efficient workflow from site planning to detailed design. Real-time data updates reduce errors and eliminate redundant data entry. It also provides insights into sunlight exposure, noise levels, and wind conditions to support architectural design and construction. This data-driven approach improves efficiency and sustainability and has been successfully used in Denmark, France, Germany, and Norway. (Spacemaker 2024).



Fig. 12. Using AI technology to explore urban design options in minutes for architects, urban designers, and developers. *Source:*

<https://www.archdaily.com/952850/spacemaker-proposes-ai-powered-generative-design-to-create-more-sustainable-spaces-and-cities>

AI improves efficiency and execution in landscape and site design. VectorWorks, a platform for intelligent landscape design, uses AI to integrate BIM models, detailed data, and advanced workflows. It supports the entire process from concept to construction.

VectorWorks enables the rapid generation and assessment of multiple design schemes while seamlessly integrating with traditional tools like Revit, CAD files, and Rhino, promoting multi-tool collaboration (VectorWorks 2024). These AI-driven tools, now widely applied in real-world projects, provide innovative and efficient support to design teams.

2.2.3 Artificial Intelligence and Smart Cities

“As urbanization accelerates, climate change worsens, and social challenges grow, integrating AI, IoT, and big data into urban systems becomes essential. (Allam and Dhunny 2019) “These technologies improve resource management, enhance quality of life, and support sustainable urban development, making smart cities a necessity.

“With the rise of sensors, mobile internet, and computing systems, cities can now collect and process data more efficiently. Technology forms the foundation of smart cities. Big data, powered by IoT, spans multiple fields, while AI processes and analyzes vast amounts of information (Allam and Dhunny 2019)“. Consequently, AI applications in smart cities have made significant progress.

The global use of AI in smart cities is expanding. In 2019, UN-Habitat and China launched the AI4City project, led by UrbanX Lab, to explore AI in transportation, energy management, and building automation. The project aims to set global standards, ensure data security, and promote cross-sector collaboration, serving as a model for innovation and sustainability(UN-Habitat 2019).

The next sections of this thesis will examine how AI improves urban livability, strengthens governance, supports sustainability, and helps combat climate change. Also with the potential challenges and risks.

Enhancing Urban Livability in Smart Cities

Improving urban livability with a human-centered approach is a key goal of smart cities. AI helps cities create cleaner and more efficient environments. It reduces pollution and congestion. This is important in times of economic uncertainty, climate change, and post-pandemic challenges.

Case Studies: Helsinki's Experimental Communities

Helsinki applies AI to improve urban life in **Kalasadama** and **Jätkäsaari**. These districts use AI to optimize resources, improve transportation, and develop new services.

Kalasadama, once an industrial port, now tests AI solutions for better living. AI-powered digital twins optimize energy use, waste management, and transport. "The goal is to create a district that uses resources so intelligently as to give residents an extra hour of free time each day" (Mantelli et al. 2024).

This goal is being achieved through automated waste collection and AI-powered transport. Residents take part in pilot projects to ensure solutions meet real needs. This improves both livability and sustainability.

Jätkäsaari applies AI to improve mobility and accessibility. It tests autonomous vehicles and smart public transport. AI analyzes real-time traffic data and resident feedback to reduce congestion and improve connectivity (Mantelli et al. 2024).

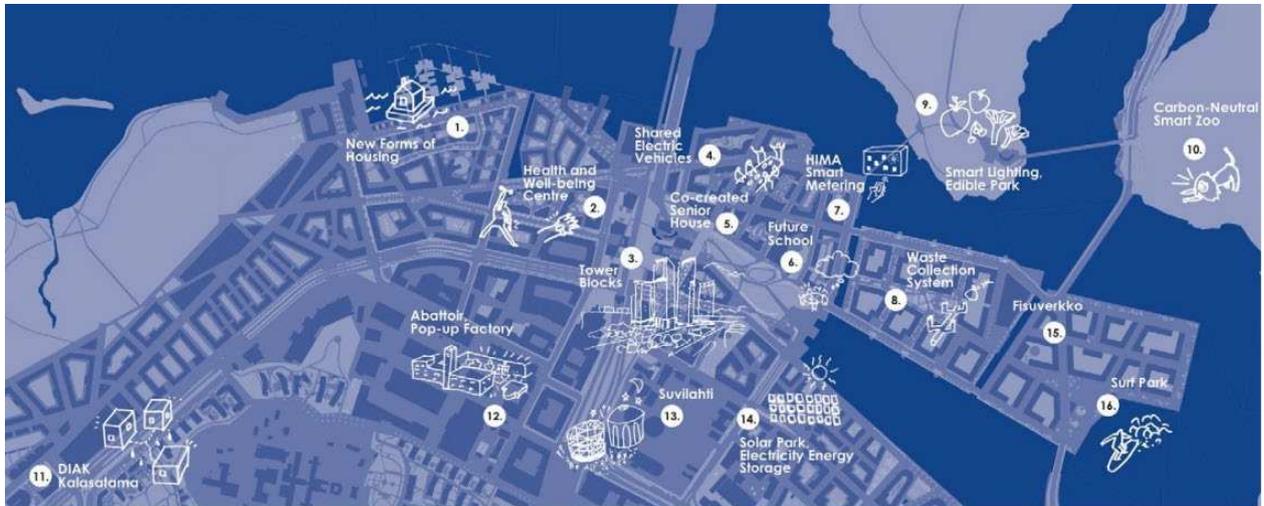


Fig. 13. Smart Kalasatama map.

Source: <https://fiksukalasatama.fi/en/building-blocks/project-portfolio/>

Jätkäsaari has invested in pedestrian and cycling infrastructure. It uses AI and real-time data to improve safety and efficiency.

AI has great potential to enhance urban livability. With better AI technologies, autonomous driving, and more public involvement, cities can learn from projects like Kalasatama and Jätkäsaari. Global efforts toward sustainable development also benefit from these insights.

AI is changing how urban livability is assessed and managed. Many smart city evaluation frameworks focus on promotion but lack clear strategies for long-term resilience and livability. AI-driven methods offer data-based insights that help cities make better, more sustainable decisions (Kutty et al. 2022).

AI tools process large datasets in real-time. They analyze environmental conditions, transportation, energy use, and resident feedback. These systems help city managers learn from global best practices, assess urban performance, and improve livability.

Enhancing Urban Governance

The use of data and technology in urban governance began in the mid-19th century. During a cholera outbreak in London, researchers mapped cases and found a link between contaminated water and high mortality. This helped the government to improve water systems and add pipe insulation, reducing future outbreaks (Allam and Dhunny 2019).

Today, AI, machine learning, and deep reinforcement learning play a key role in urban management. These technologies improve traffic control, cybersecurity, energy grids, unmanned aerial networks, and AI-driven medical systems (Caprotti and Liu 2022).

Many cities worldwide have been testing these technologies for years, making significant progress in areas such as traffic management and emergency response:

1. **Hangzhou's City Brain:**

Many cities have tested AI in traffic management and emergency response. Hangzhou's City Brain, launched in 2016, uses cloud computing to optimize traffic flow. It combines data from traffic signals and cameras to make real-time adjustments (Caprotti and Liu 2022). The system creates "green light corridors" by changing signals for emergency vehicles. It also reduces congestion and travel delays. Data shows a 15.3% increase in travel speed, a 9.2% drop in congestion, and a three-minute reduction in travel time per passenger. (Caprotti and Liu 2022).

2. **Mind City in Venice:**

AI also helps cities manage unique challenges. Venice's Mind City system tracks its lagoon environment, and over 20 million tourists each year. A smart control room integrates data from transport agencies, the city government, and local police. This system improves city operations and urban management (Fabbricadigitale, 2020).

3. **AI-Driven Governance in Shanghai:**

Shanghai, a megacity with **25 million residents**, applies AI to control traffic, improve public service efficiency, and enhance emergency response. AI solutions help the government to manage the challenges in large cities.

Climate Adaptation and Sustainability

Global warming, rising sea levels, and extreme weather events like floods, wildfires, and heatwaves are increasing. These challenges create more **climate refugees** and disrupt agriculture, worsening the global food crisis. AI is becoming a key tool in climate adaptation. It uses high-resolution modeling and data analysis to improve climate predictions and decision-making (Allam and Dhunny 2019). AI processes large datasets, studies past and real-time climate data, and identifies trends. It also strengthens early warning systems and improves disaster response. These tools help reduce damage, protect lives, and lower economic losses.

AI also supports agriculture in fighting climate change. Combined with large databases, it improves resource efficiency, increases crop yield and quality, lowers costs, and enhances ecological conditions. It uses data sensing, intelligent control, and pest and disease prediction to make farming more sustainable (Li et al., n.d.). In the future, AI is expected to further strengthen agriculture's ability to handle climate challenges and reduce food shortages.

AI also helps reduce climate impact at its source. Smart waste management, carbon removal technologies, and renewable energy systems lower carbon emissions. By improving urban livability, optimizing resources, and strengthening governance, AI plays a major role in tackling climate issues. These innovations are essential for global sustainability and addressing one of humanity's greatest challenges.

2.3 Today's AI applied on Architectural Design Field

AI has been used in architectural design for many years. It integrates different technologies to improve and optimize design processes. Genetic algorithms and evolutionary computation refine design solutions. Neural networks learn spatial patterns. Fractal techniques and cellular automata generate complex geometries. Swarm intelligence supports dynamic design and collaborative optimization (Pena et al., 2021).

This thesis will examine AI in architectural design from three perspectives: generative AI, parametric design, and AI in sustainable architecture.

2.3.1 Generative AI on Architectural Design

Generative AI Introduction

Generative Artificial Intelligence (GenAI) is a type of AI that generates new text, image, and video material by identifying patterns in training data. These models react to natural language, communication is creative and intuitive. (Wikipedia, 2024a).

The rapid growth of GenAI comes from advances in deep neural networks, especially Transformer-based models like large language models (LLMs). Popular applications include ChatGPT for text, Stable Diffusion, Mid-Journey, DALL·E for images, and Sora for videos. Major companies like OpenAI, Google, and Microsoft lead in development, with contributions from smaller firms (Wikipedia, 2024a).

With new deep learning methods, GenAI is developing quickly. Transformers for improved sequence processing, Generative Adversarial Networks (GANs) for realistic images, diffusion models for high-quality visuals, and Variational Autoencoders (VAEs) for learning data structures are important technologies. Nowadays, a lot of architects use diffusion models. (Li et al. 2024).

Many image-generation models use diffusion-based methods to create high-quality visuals from text. These models train on vast datasets, often with billions of web-sourced images, improving accuracy and diversity in outputs.

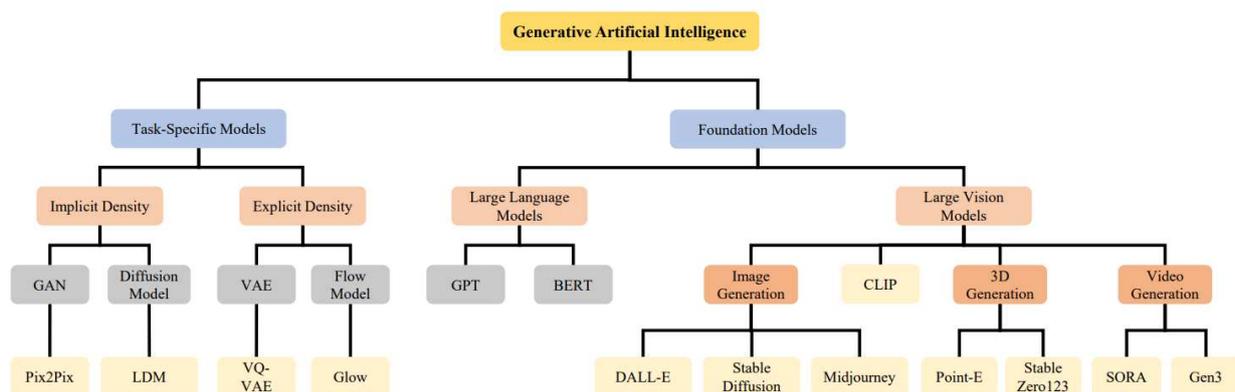


Fig. 14. Types of generative artificial intelligence models.

Source: Li et al. 2024. <https://www.sciencedirect.com/science/article/pii/S209526352400147X>

Generating high-quality images from text has long been a challenge in computer vision. **Diffusion models (DMs)** have greatly improved this process. Image generation usually happens in two steps. First, the model creates a low-resolution image. Then, it adds details to produce a high-resolution, realistic result.

With better technology, DM models can now generate and edit images based on text. This makes them more useful for designers. Although their applications and processes vary, major tools like Stable Diffusion, Mid-Journey, and DALL-E all follow the same diffusion principles.

Although a completely integrated workflow has not yet been created, generative AI is currently utilized in some phases of architectural design. Text-to-image tools aid in the exploration of styles and the development of fresh visual concepts in conceptual design. AI is currently insufficiently accurate for 3D modeling of intricate architectural models. Nonetheless, programs such as Magic3D are capable of producing simple architectural shapes and evaluating environmental performance.(Pena et al., 2021).

AI-powered programs, such as ArchiGAN and Finch, can rapidly provide useful floorplan designs for residential house and apartments. They use sketches or text inputs to create the layouts. Image-based models, such as Pix2Pix, assiste in the creation and improvement of facade aesthetics in facade design. Additionally, AI enhances structural layout optimization, which increases construction efficiency and safety. (Pena et al., 2021).

Generative AI in conceptual design is still developing, but text-to-image tools have made significant progress. These tools also extend to text-to-3D model generation, video synthesis, and floor plan creation. AI supports façade design, structural layout, and other design tasks. However, integrating these tools into a seamless workflow is still a challenge. Case studies provide insights into their use and impact on architectural design.

Text-to-image generation							
Modern residential building	A cute orange cat, dressed in palace attire, with raised paws, furry and adorable.	A small kitchen with a low ceiling.	A modern architectural building with large glass windows, overlooking a serene ocean at sunset.	A cute corgi lives in a house made out of sushi.	A warm room, floor-to-ceiling windows, sunlight, cat.	A chair made of brick.	matte painting of a castle made of cheesecake surrounded by a moat made of ice cream
Adobe Firefly	Midjourney	Glide	DALL-E3	Imagen	Stable Diffusion XL	Text2Mesh	DreamFusion

Fig. 15 Some examples of generated results from image generation models.

Source: Li et al. 2024. <https://www.sciencedirect.com/science/article/pii/S209526352400147X>

	single	single	double	double	triple	multiple	
sawtooth							thin
topographic							linear
cantilevered							perpendicular
gap							oblique
concave							vertical
gridded							horizontal
	spiraling	carving	zigzagging	intertwining	arraying	packing	

Fig. 16 AI generated massing from variation in entities, directions, operations and affects.

Source: Kim et al. 2023.

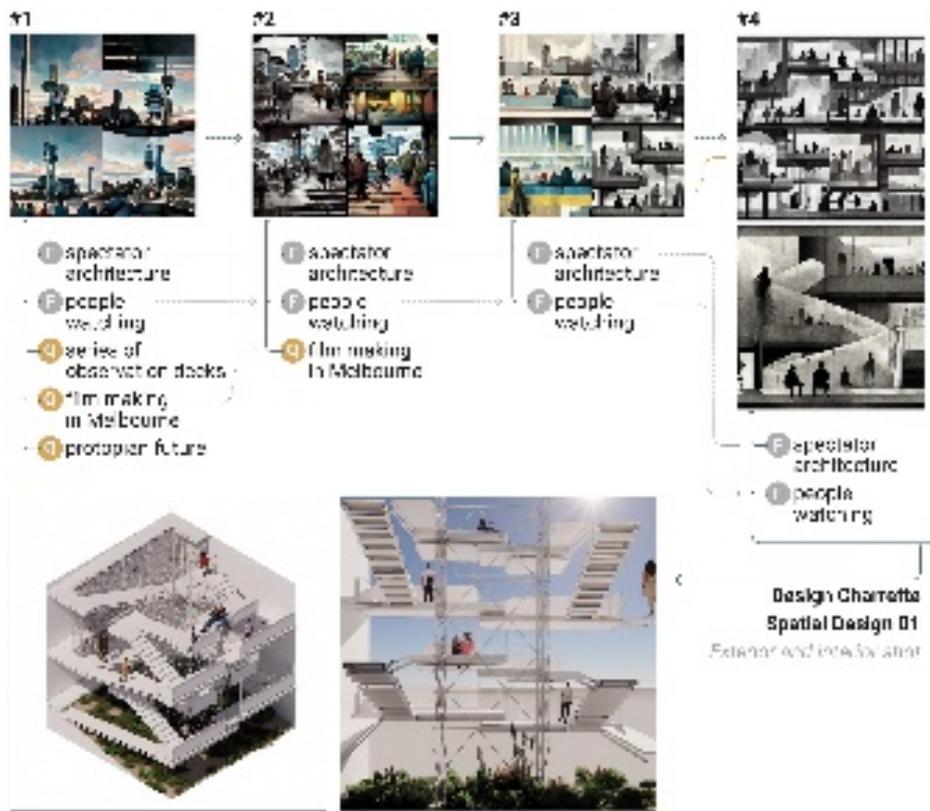
https://www.researchgate.net/publication/373995010_Text2Form_Diffusion_Framework_for_learning_curated_architectural_vocabulary

Image Generation AI case studies

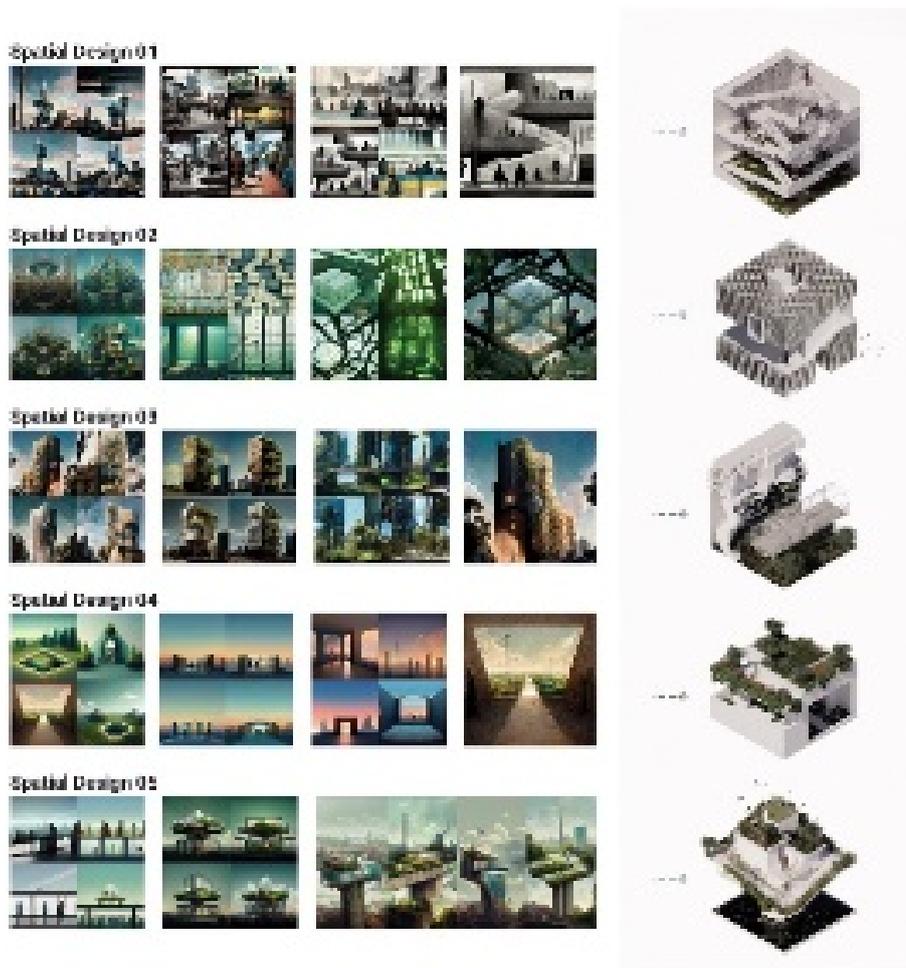
AI image generation is changing workflows in creative industries. Researchers have studied how Mid-Journey, a well-known text-to-image tool, helps architects in design. It supports divergent thinking, which generates broad creative ideas, and convergent thinking, which refines specific concepts (Tan and Luhrs 2024).

In a case study, designers used Mid-Journey to create user personas. They entered descriptive keywords to generate images. Then, they refined these images through iterations, developing detailed virtual profiles (Tan and Luhrs 2024). The AI-generated images inspired the design of buildings with diverse functions. Unique spatial structures resulted from this. The close connection between the photos and the finished designs demonstrates AI's potential as a creative tool, even though architects provided the majority of the originality.

This process not only sped up the definition of user needs and reduced the cognitive load on designers but also introduced new inspiration by quickly generating unexpected visual effects. It demonstrates how AI can serve as a valuable tool for enhancing both creativity and efficiency in architectural design.



(a)



(b)

Fig. 17. Interacting with Midjourney to develop one space (a) and develop five spaces (b).

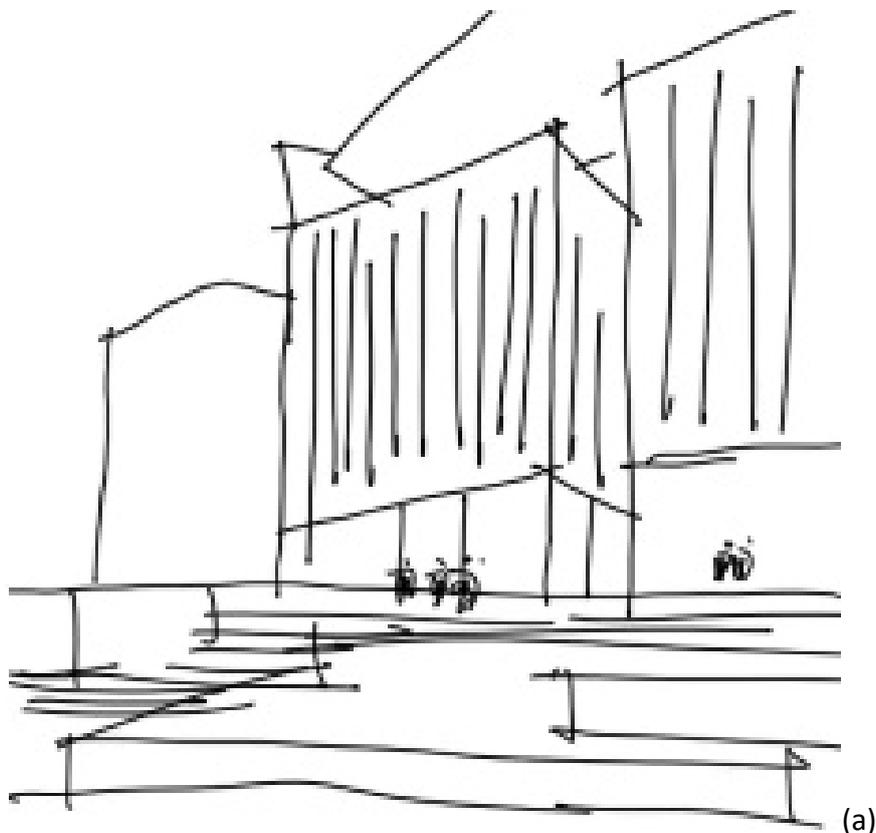
Source: Tan and Luhrs 2024.

<https://www.tandfonline.com/doi/full/10.1080/14606925.2024.2353479#d1e430>

However, in specific design projects, when used with careful and professional oversight, image-generation AI tools have demonstrated the ability to directly produce final design proposals for client presentations.

In the "**Rainy Street**" project, Shanghai Duyan Architectural Design Studio leveraged AI tools such as Mid-Journey, Stable Diffusion, and Runway to complete the entire workflow—from initial sketches to the final proposal. Designers started with simple hand-drawn sketches and used keyword descriptions to integrate AI into the design process. This covered key stages like concept development, sketch refinement, material selection, and animation generation.

AI improved efficiency by generating over 20 preliminary concepts in a short time. Through iterative adjustments of keywords and parameters, it produced architectural designs with a strong commercial feel and innovative forms (Qingnian Jianzhu 2022). By combining the professional judgment of architects with AI-generated visuals, the project achieved a balance between cost efficiency and aesthetic appeal.





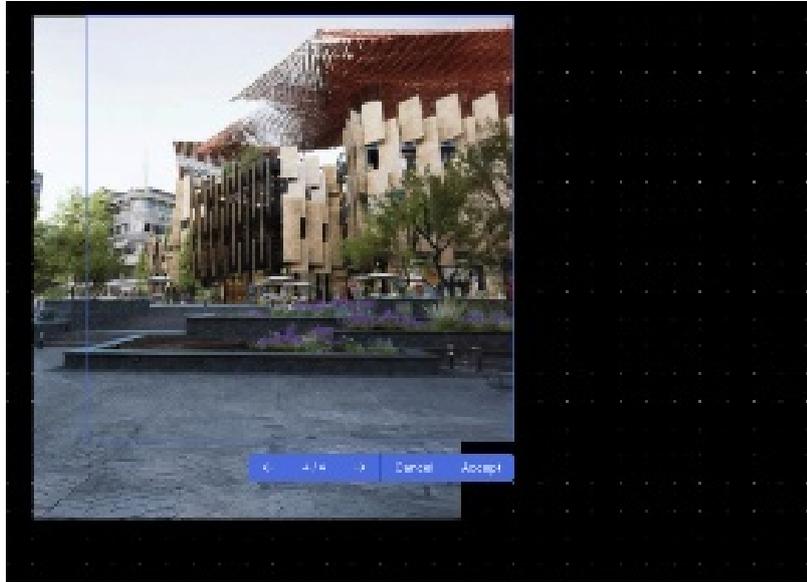
(b)



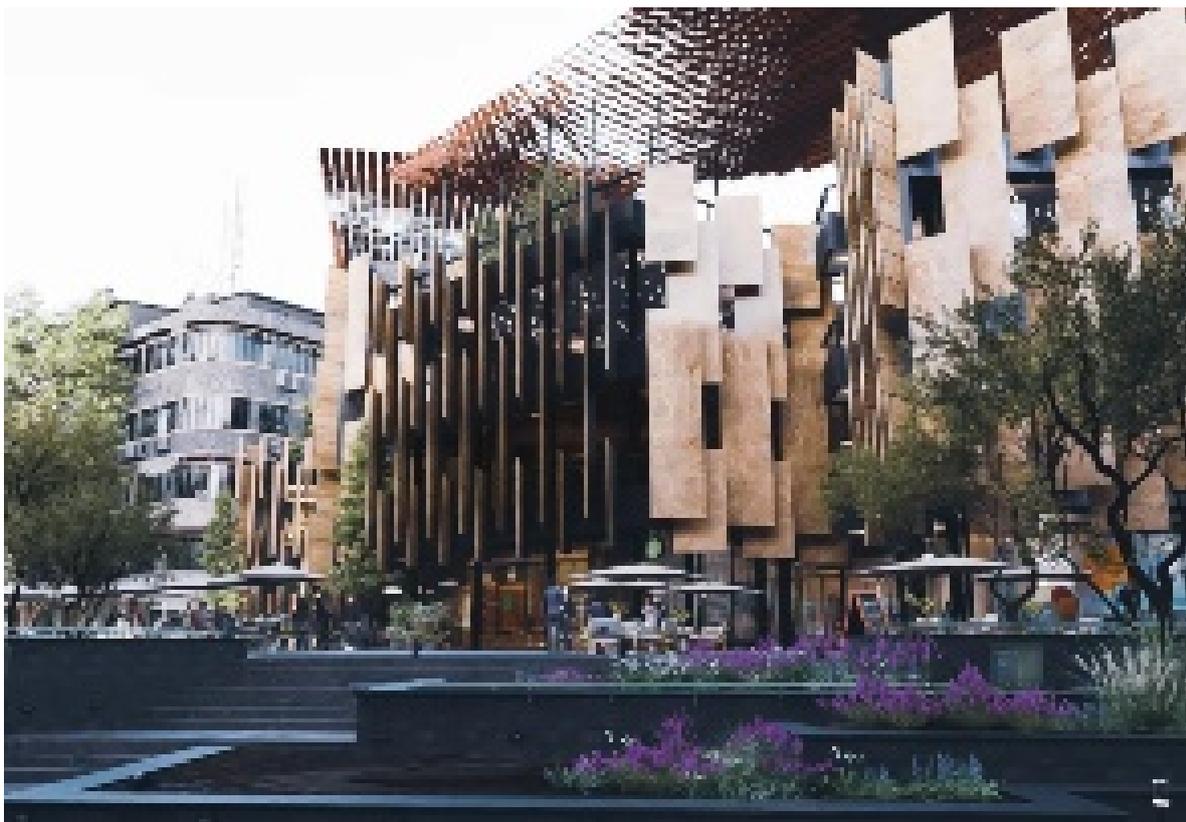
(c)



(d)



(e)



(f)

Fig. 18. The process of using image generation tools to design the project from: sketch (a), different art or design styles(b), design development (c), image expansion (d), to the final design render (f).

Source: https://mp.weixin.qq.com/s/_cgW1HrzuJuLGhI2WZbKKQ

Despite their benefits, current image-generation AI tools have several limitations. One major issue is that they mainly produce two-dimensional images. Designers must manually convert these into three-dimensional architectural models, as existing 3D model AI tools lack precision and usability.

These tools also rely heavily on precise keyword inputs. This requires designers to have strong language skills and clear descriptions. Frequent software updates can cause inconsistencies, especially in real-world projects. Another concern is copyright ownership, which remains a key issue when using AI-generated content.

These challenges show the importance of designers applying their expertise to refine AI tools. As technology improves, image-generation tools are expected to offer even greater potential in creative design.

2.3.2 AI on Parametric Architectural Design

Parametric design Introduction

Although **parametricism** has its roots in the digital animation techniques of the mid-1990s, its core lies in making architectural elements adjustable, diverse, and adaptable to each other. "These elements can flexibly respond to external environmental conditions and internal usage states. Compared to the more rigid and singular ideal paradigms of previous architectural styles, this is the most critical distinction," explained Patrik Schumacher from Zaha Hadid Architects (YouFang 2019). In other words, a design approach that enables architectural transformations through data-driven changes can be referred to as parametric design.

The development of computer-aided design tools and technologies has facilitated the advancement of parametric design. In addition to responding to input conditions in real time, another advantage of parametric design is the ability to create real-time, adjustable digital models. However, architects using these tools are still in the minority, as most architectural design is still carried out using traditional methods.

Parametric design was initially applied to explore various forms and iterations, particularly in architecture characterized by fluid, curvilinear shapes. The **Heydar Aliyev Center** (2007–2012) exemplifies the implementation of parametric design principles in both design and construction. Zaha Hadid's team used Rhino and Grasshopper to establish a parametric rule-based system, enabling them to explore multiple forms and curves, ultimately achieving the center's smooth and dynamic architectural language. By analyzing light and shadow interactions, they ensured that the building maintained a striking visual impact from all angles, while optimizing spatial functionality. This design approach has been widely adopted in the firm's other projects, and continues to play a crucial role in the refinement of architectural designs. A similar parametric strategy is seen in the **Guangzhou Opera House** in China, which features interlocking panels that respond to environmental changes (Hegazy and Saleh 2023).



Fig. 19. The Heydar Aliyev Centre (a) and Guangzhou Opera (b).

Source: <https://www.zaha-hadid.com/architecture/heydar-aliyev-centre/> (a)
<https://www.zaha-hadid.com/architecture/guangzhou-opera-house/> (b)

AI's capabilities in analysis, prediction, and generation can elevate parametric design to an entirely new level. AI has the potential to help designers use parametric design more freely while expanding its possibilities. Traditional parametric tools have a steep learning curve, and their related knowledge is not typically included in conventional architectural education, making their application somewhat challenging. AI can assist designers in mastering parametric design tools more quickly.

Additionally, AI's data-processing capabilities extend the creative potential of traditional parametric designers, broadening design possibilities and improving efficiency. By automating repetitive tasks, AI allows designers to focus more on creativity and innovation, freeing them from time-consuming iterative processes.

The integration of ChatGPT with commonly used parametric design tools, such as Grasshopper and Dynamo, is a strong example of how AI enhances parametric design. ChatGPT allows

designers to generate Python scripts using natural language, which can be directly implemented in Grasshopper or Dynamo. This enables dynamic adjustments and optimizations of curves and forms, as well as the creation of BIM components, reducing modeling time and increasing design flexibility.

Traditionally, designers using parametric design methods often have to switch between the roles of "programmer" and "designer." However, with AI assistance, mastering this design approach becomes more accessible. AI simplifies parameter adjustments by allowing designers to define complex parametric requirements using natural language, eliminating the need for deep programming knowledge. As technology advances, adopting these methods will become even easier, further lowering the barrier for architects to integrate parametric design into their workflow.

Case Studies

Many scholars have conducted research on the application of AI in parametric design, including integrating form and performance more effectively. A computational approach that incorporates designer preferences into an interactive evolutionary algorithm, has been proposed (Mueller and Ochsendorf 2015). This method adjusts mutation rates, generation numbers, and parent selection to guide spatial exploration in design. Their study, which includes numerical parameter analysis and case studies, demonstrates that this approach allows for flexible exploration patterns, balancing performance optimization, design diversity, and qualitative objectives.

In the area of AI-driven morphogenesis in design, An evolutionary feedback design framework that integrates parametric design, automation, and multi-objective optimization has been proposed (Lin and Gerber 2014a; 2014b). It provides fast energy performance feedback, helping architects make early design decisions. They used genetic algorithms to optimize different tasks and balance conflicting goals. Their study shows that this system allows architects to make better and faster design choices.

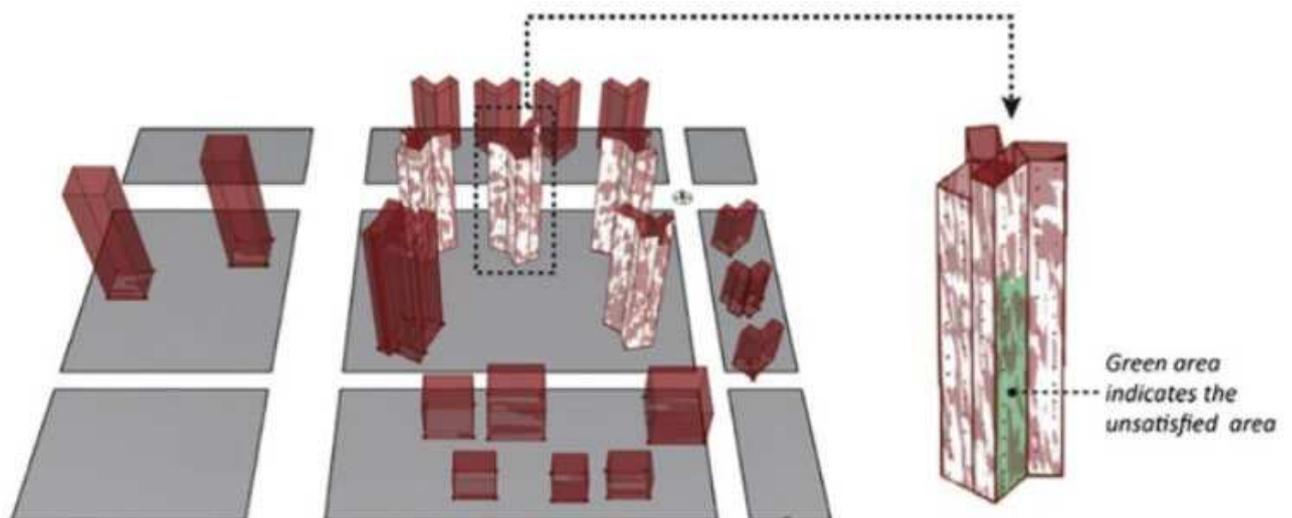
Similarly, A method for optimizing high-rise apartment layouts based on daylight requirements was developed using NURBS (Non-Uniform Rational B-Splines) and genetic algorithms. The layout is first created using NURBS, and then simulation tools analyze daylight conditions. The design evolves step by step until it ensures at least two hours of sunlight, on the winter solstice (Yi and Kim 2015).



(a)

Fig. 20.a. Eight successive generations in an optimization-based exploration, where user selection is primarily guided by quantitative performance. *Source: Mueller and Ochsendorf 2015.*

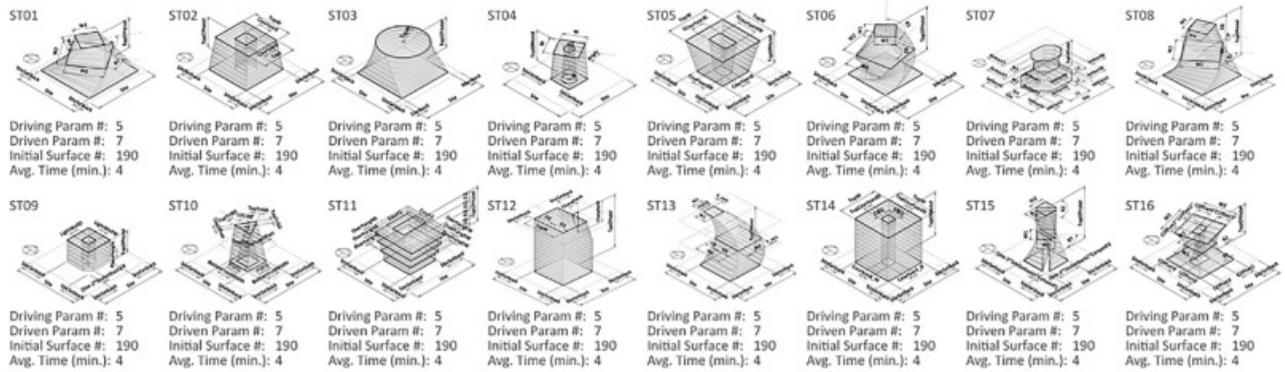
https://www.sciencedirect.com/science/article/abs/pii/S0926580515000308?casa_token=LsbHEWqrV40AAAAA:CDzsrZgBIO1PUyMPIWxChUsqaT8tqBC-3SxgeNXXI-_GC6L6AaVQKQWFz9wKNyOY1fNB_Dtg8



(b)

Fig. 20.b. Captured image indicates the unsatisfied area of sunlight access. *Source: Yi and Kim 2015.*

https://www.sciencedirect.com/science/article/abs/pii/S0038092X14005398?casa_token=oF7KVgng h1MAAAAA:pbY2JIHMU2L9LWvkDhB1cq2QcvdMXG1QEhHzHWYOI_Sd_2u1lgjlc16a6QITKebT3GNgK18jWMI



(c)

Fig. 20.c. Diversity in participants' parameterization. *Source: Lin and Gerber 2014a; 2014b.*

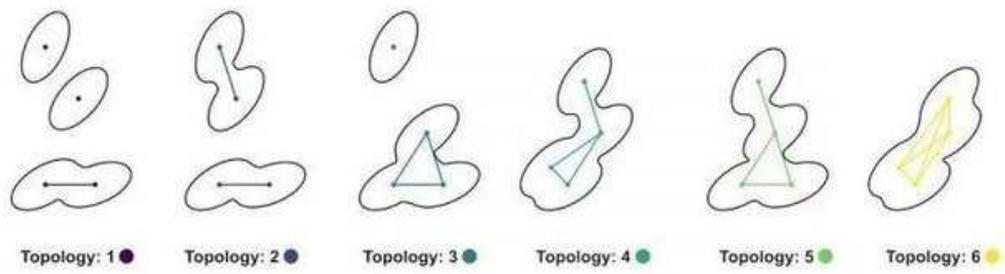
https://www.sciencedirect.com/science/article/abs/pii/S0378778814006768?casa_token=sGtueubHQU4AAAAA:P7KC3zpxBdzvxqjEfd-a-pEhtbZ--A8uNZNyJpGPckH9Z0qemk9sVvrFmtDB3wLm1PRm2R1pJnWw

In the practical application of AI in parametric architectural design, Zaha Hadid Architects remains at the forefront. The Chengdu Science and Technology Island project is a good example. The urban design adopts the concept of water lilies, with forms resembling blooming lotus flowers. However, unlike traditional architectural methods, these shapes were generated through topology-based computational optimization.

Efficient algorithms greatly optimized the forms of these complex structures. The sizes and dimensions of the buildings were determined through iterative calculations using genetic algorithms, based on parameters such as sunlight, sightlines, connectivity, and landscape integration. The first building of the development's initial phase has already been completed recently.



(a)



(b)

Fig. 21. a,b The lotus-shaped forms are iteratively calculated through genetic algorithms, considering connectivity, sunlight, and sightlines (a) and certain typologies (b).

Source: <https://www.zaha-hadid.com/architecture/unicorn-island-masterplan/>



(c)



(d)

Fig. 21. c,d Chengdu Science and Technology Island urban (c) and architecture design (d).

Source: <https://www.zaha-hadid.com/architecture/unicorn-island-masterplan/>

2.3.3 AI on Sustainable architectural design

Sustainable Architectural Design AI

No matter what design method is used, a large number of buildings are constructed every year, and sustainability is a key factor for each one. Unfortunately, traditional precedent-based design processes do not always prioritize sustainability —whether financially, environmentally, or culturally.

There have been many attempts to create comprehensive design environments, but success has been limited. These efforts include organizational theory, social networking, design theory, methodology, building information modeling (BIM), process modeling, model-based analysis, multidisciplinary design optimization, decision science, human-computer interaction, economics, and artificial intelligence (Haymaker 2011).

From concept design to completion, architectural projects involve many stakeholders, take a long time, and have numerous variables. Achieving sustainable design requires a more scientific approach. The adoption of Building Information Modeling (BIM) has been a major advancement, especially for large and complex projects.

Good data management, a scientific design approach, and effective communication processes can greatly enhance a project's sustainability.

In the concept design phase, AI's data processing capabilities offer a natural advantage in improving building sustainability compared to traditional manual methods. However, since many factors influence the design process, it should still be led by architects.

Case studies

An AI application in the concept design phase of a tourism project has been shown to improve energy efficiency and indoor thermal comfort (Si et al. 2019). The researchers also used artificial neural networks to optimize building forms and reduce computation time. They evaluated four multi-objective optimization algorithms—NSGA-II, MOPSO, MOSA, and ES—and found that NSGA-II performed the best overall. The optimized design significantly improved building performance, showing the effectiveness of this method in complex architectural design issues.

Additionally, in the concept design of super high-rise buildings, AI has great potential to enhance sustainability. Computational architectural phenotypes have been explored through evolutionary and swarm optimization to enhance sustainability, cost efficiency, functionality, and structural performance (Ekici et al. 2019). Their framework consists of three stages: form generation, performance evaluation, and optimization, aiming to identify the most performance-efficient geometric form, in the early design phase.

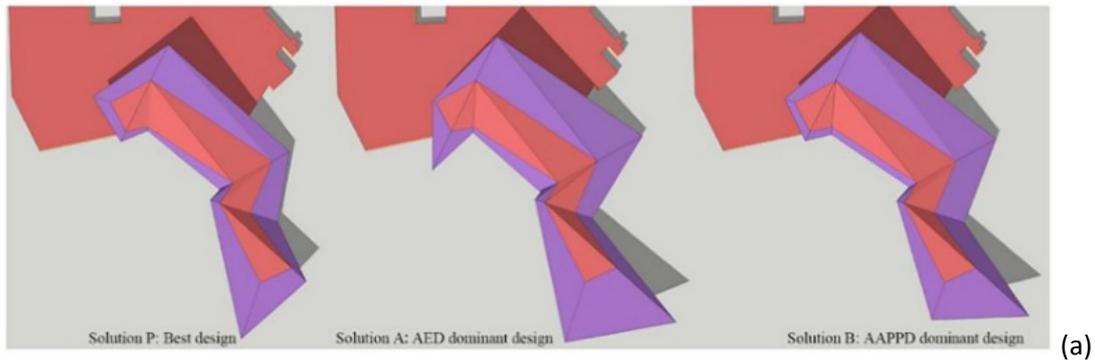


Fig. 22.a. Shape of the eaves of different design solutions. *Source: Si et al. 2019.*

https://www.sciencedirect.com/science/article/abs/pii/S1474034618306128?casa_token=BPpEq7UkNbQAAAAA:JXxG-Ef2dmf7FepC2cJTgj8A5Sfrci7luzVY32Sph7T9fEm-yJEclzXiGPMPDNogo539i10g6dA

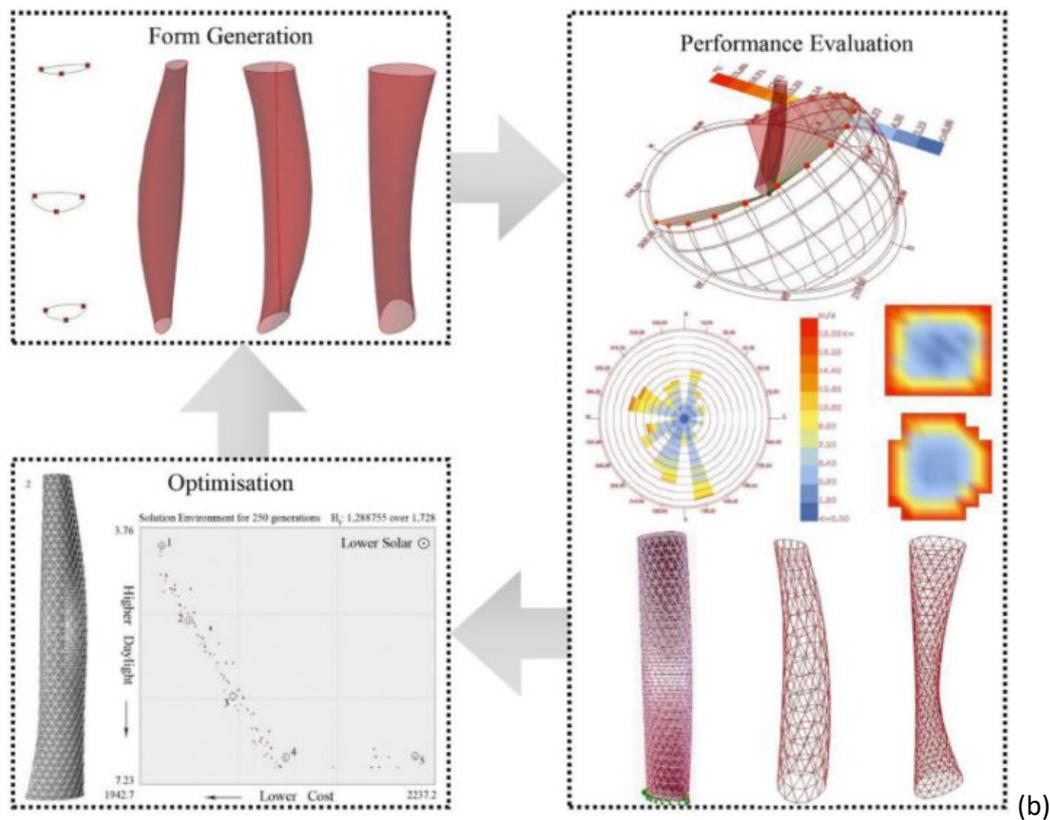


Fig. 22.b. Performative computational architecture framework. *Source: Ekici et al. 2019.*

https://www.sciencedirect.com/science/article/abs/pii/S0360132318306413?casa_token=T4DssHEgDvoAAAAA:yiUkc89ny4YuwL3gnYeumgmW8ffHWI8lo3Twvd4iBxHINiRmZ7rXvAdd8abojfgKBMrIw-JOu_k

AI has also been applied in sustainable architecture and concept design practice, helping architects optimize energy efficiency, building forms, and design decisions. For example, in the **Virginia Tech Innovation Campus project**, AI generated and optimized over 1,400 building

massing options, meeting spatial requirements while maximizing solar energy potential and reducing enclosure costs.

Additionally, the architectural design team **SmithGroup**, in collaboration with Oak Ridge National Laboratory, used machine learning to train energy models. By analyzing 4.7 million design iterations, they predicted building energy consumption and provided real-time design feedback, to enhance sustainability.

AI also supports pattern recognition, analyzing large datasets to optimize room layouts and building configurations. This enables architects to explore design possibilities more efficiently, promoting smarter, and user-friendly built environments.

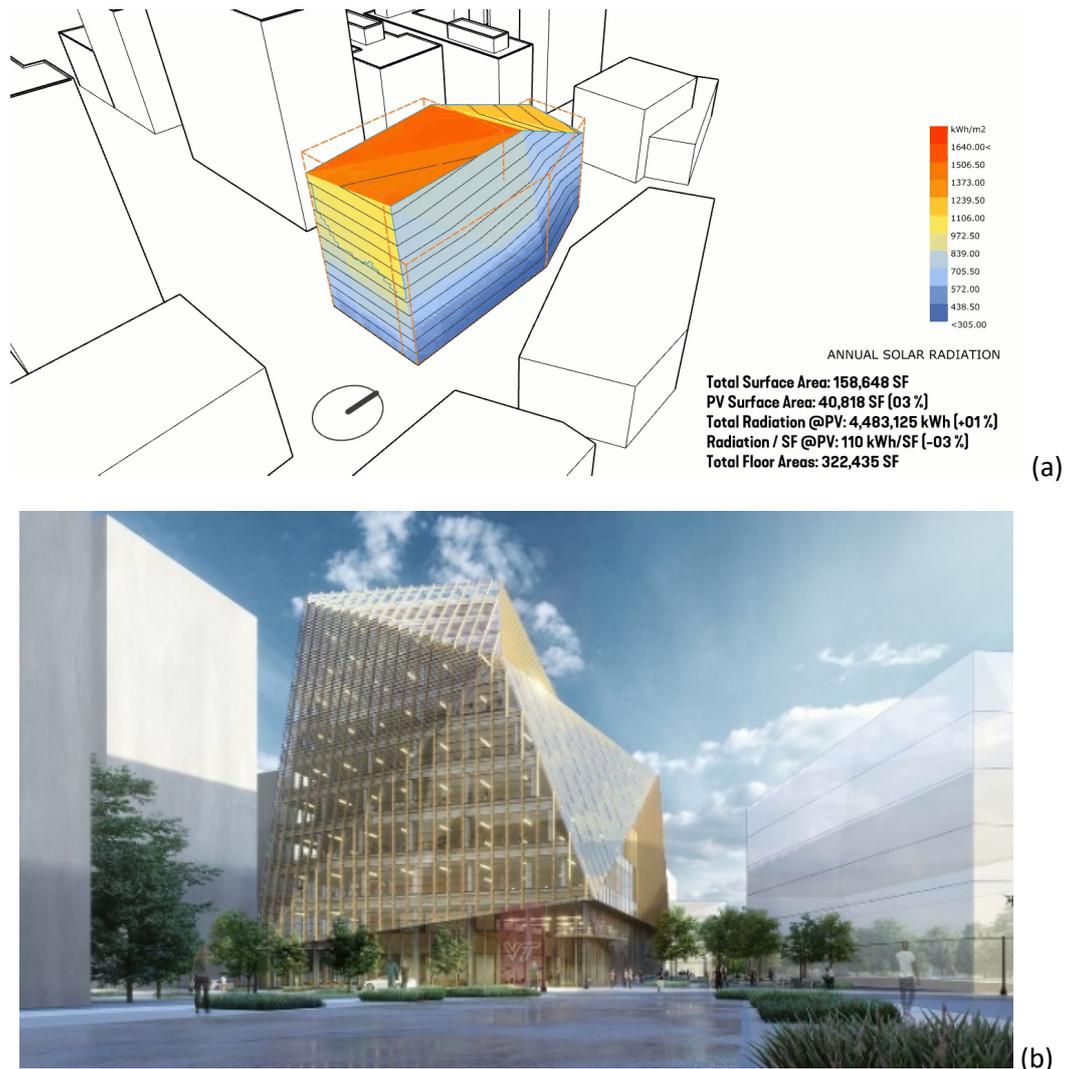


Fig. 23. Square footage and potential PV output were simultaneously plotted and optimized with each new massing iteration (a) and final design rendering with PV on the roof and façade (b).

Source: <https://www.smithgroup.com/perspectives/2024/beyond-imagery-the-application-of-ai-to-architectural-design>

2.4 Conclusion and Challenges

The integration of AI into architectural and urban design has brought a significant shift in how designers approach their work. As discussed in Sections 2.1 to 2.3, AI tools have proven to be powerful in enhancing creativity and efficiency, allowing for the rapid exploration of innovative solutions, that surpass the limitations of traditional design methods. By leveraging advanced algorithms, designers can generate and evaluate multiple options in a fraction of the time, unlocking new possibilities in conceptualization and ideation.

Additionally, AI's ability to process vast amounts of data provides designers with valuable insights into environmental factors, urban dynamics, and user behaviors. This **data-driven approach** ensures that design outcomes are not only innovative, but also responsive to context and sustainability requirements. Furthermore, AI fosters interdisciplinary, collaboration between architecture, engineering, and data science, enabling more integrated and holistic problem-solving.

In conclusion, AI has become a **transformative force** in architectural and urban design, reshaping workflows, and expanding creative possibilities. Its thoughtful application allows designers to tackle complex challenges with greater precision, efficiency, and adaptability, paving the way for a more innovative and responsive future in design.

Meanwhile also face certain challenges:

Cultural Understanding: Risk of Homogenized Design

A major concern is whether the widespread use of AI in design will lead to homogenized styles, erasing local cultural identities. Contemporary design tools already show signs of converging methodologies, and if AI establishes a uniform approach, reliance on similar data may further intensify this trend. This raises critical questions about how AI can integrate cultural diversity to prevent the loss of context, in architectural design.

Overreliance on AI: Maintaining Human Judgment and Moral Values

The high efficiency of AI in design may lead to overreliance, risking the neglect of critical design aspects. Maintaining human judgment and ethical values is essential in decision-making. Designers must critically evaluate AI-generated outcomes to ensure that ethics, emotions, and cultural nuances are not overshadowed by algorithms.

Data Dependence and Design Convergence

The quality of AI-generated design depends on the training data, but this reliance introduces risks such as security threats, privacy concerns, and biased outcomes. Furthermore, using similar data sources across regions may reduce diversity, reinforcing dominant trends instead of encouraging innovation, or locally relevant solutions. As a result, AI-driven designs may fail to reflect the unique characteristics of individual communities.

Job Displacement in the Design Industry

As in many fields, the growing use of AI in design raises concerns about job displacement. While AI enhances efficiency and creates new opportunities, it may reduce demand for roles involving repetitive or technical tasks. Adapting the workforce, redefining design roles, and emphasizing human creativity, critical thinking, and cultural sensitivity—qualities AI cannot replicate—will be essential.

Data Security and Privacy Concerns

AI systems rely on large datasets for training, raising concerns about data security and privacy. Designers and organizations must ensure ethical and legal compliance in data collection and usage. Balancing high-quality, diverse datasets with privacy protection remains a key challenge in AI-driven design.

Chapter 03: Conceptual Design Process and Competition Introduction

3.1 Conceptual Design phase and traditional process

The paradigm of design activities is undergoing deep transformation. In response to this trend, it is imperative to adopt a more pragmatic and proactive approach, leveraging collaboration, AI support, and information technology to comprehensively drive innovation and enhance efficiency in design practices (Wang et al., 2002).

3.1.1 Conceptual Design phase

Conceptual design is a critical phase in architectural and urban design projects, shaping the project's core ideas, forms, and spatial arrangements, while also significantly impacting project costs. Early completion of the design is advantageous, as the cost of design changes increases substantially in later stages. However, existing computer-aided design tools, such as Building Information Modeling (BIM), are better suited for later project phases and are less effective, in supporting designers during the early stages (As, Pal, and Basu 2018).

At the same time, the conceptual design phase is inherently complex, integrating various factors and serving as a creative process that combines rationality and intuition. It relies on the designer's project experience, cognitive abilities, professional knowledge, and inspiration, along with human-computer interaction skills and communication, and coordination capabilities across multiple dimensions.

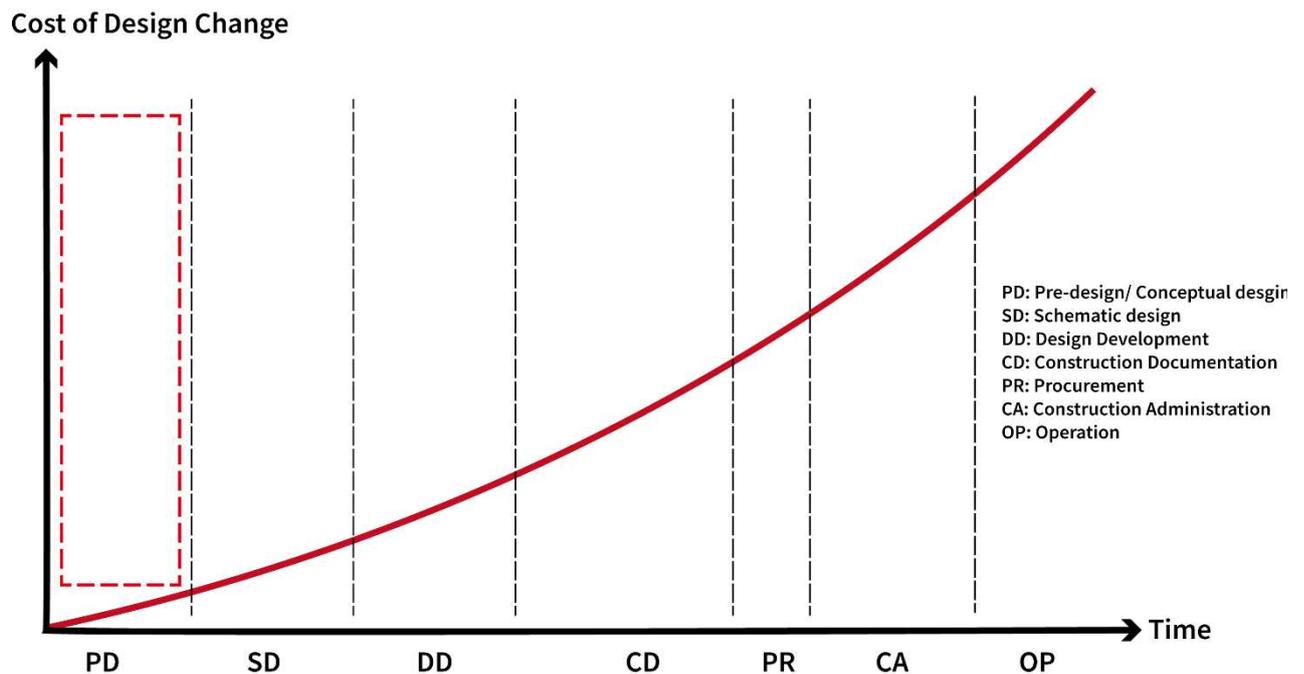


Fig. 24. The curve shows the various building phases in chronological order on the x-axis, and the cost of design change on the y-axis.

Source: Adapted from As, Pal, and Basu 2018.

<https://journals.sagepub.com/doi/10.1177/1478077118800982>

In the conceptual design phase of urban and architectural projects, much of the professional knowledge involved is difficult to systematize and share, resulting in a high barrier to accessibility. Currently, this phase largely depends on individual designers' experience. As with many other industries, not only are resources and tools geographically distributed, but so are knowledge and expertise (Wang et al., 2002). For instance, different types of architectural projects often require the participation of "experts" with relevant experience, and past project portfolios are frequently used as evaluation criteria in design competitions. Additionally, local design knowledge and experience can be challenging to acquire, leaving external designers facing steep learning curves—one reason why consortium models are commonly adopted in bidding for projects.

The challenge of transferring cutting-edge academic research into industry practice is equally significant. Designers often face high time and effort costs to access the latest research findings and specialized knowledge, which are frequently complex, unclear in their pathways for sharing, or even closed off entirely. As a result, designers often have to rely on established personal experience for new projects, unable to "stand on the shoulders of giants" to remain up-to-date. Existing desktop design tools are mostly limited to assisting with drafting and fail to deeply integrate cutting-edge industry knowledge into design practice.

This issue also persists in the field of education. Even in the most "formal" design education settings, due to limited teaching resources, students often struggle to involve in extended, and in-depth interactions with design mentors during conceptual design. The systematic learning of many professional design concepts often requires support from supplementary courses. While these courses may appear comprehensive, the knowledge they impart is rarely deeply integrated with the individualized design tasks students are working on. This disconnection forces students to spend additional time and effort acquiring specialized knowledge through other means, though some of this knowledge remains difficult to access. This learning approach may leave students feeling a lack of effective professional support, or a loss of enthusiasm for learning. Consequently, many students graduate and enter the industry with insufficient foundational knowledge and skills.

3.1.2 Traditional Conceptual Design Process

The conceptual design process is not a single step. Even when inspiration comes, finishing the final proposal needs many rounds of changes. In urban and architectural design, the process usually includes: analyzing the design brief, researching the site, brainstorming, comparing and evaluating options, visualizing designs, and submitting the proposal.

This process depends heavily on inspiration. Inspiration can come from many sources, such as reading, traveling, personal experiences, online resources, talking to clients, consultants, and citizens, and sharing ideas within the design team. This phase is full of creativity and excitement, but it also requires a lot of time and effort, even in design firms with well-organized workflows.

Although this process is widely used by many design firms, it has some problems usually overlooked. For example, many repetitive tasks in the design process can limit creativity. However, every design mission has a deadline. Design is one phase of larger projects, with strict deadlines, especially in the conceptual phase. To finish designs on time, designers often use familiar methods. This leads to less exploration of new ideas during the conceptual phase.

In addition, presenting to team members or clients the design ideas takes a lot of time and effort. Design ideas need to be turned into visuals through traditional methods, such as sketching, creating 3D models, making renderings, and even developing presentations like animations.

Because the process is divided into more detailed tasks, there is more communication needed. This also takes extra effort from designers. For example, rendering is often done by external teams. More importantly, frequent communication with different stakeholders and making revisions take times and efforts for designers.

3.2 Competition Introduction

3.2.1 Brief Introduction

To thoroughly explore how contemporary AI tools are applied in urban and architectural design, how they influence key design stages, and whether they potentially create a new design workflow distinct from traditional processes, this thesis adopts a real-world competition as a case study. This section introduces the selected competition, while Chapters 4 and 5 delve into the specifics of conducting research and design with the assistance of AI tools. Additionally, this study aims to evaluate the process to better understand the advantages and limitations of existing AI tools compared to traditional methods, and how designers can effectively utilize them.

The chosen competition meets the following criteria: it aims to address contemporary social, economic, or cultural issues present in the urban and architectural fields and seeks to provide solutions through a comprehensive research and design process. After extensive research, and comparison of available competitions online, "**The 8th MICROHOME Kingspan Edition 2024/25**" was selected as the focus of this study.

Since its starting in 2018 and now in its eighth edition, this competition is organized by the experienced competition host "Buildner", in collaboration with Kingspan and supported by the renowned urban and architectural design platform "ArchDaily". It invites designers worldwide to rethink small-scale living solutions by conceptualizing an off-grid, modular microhome for a hypothetical young professional couple, with a maximum floor area of 25 m². The competition emphasizes creating innovative, sustainable, and aesthetically distinctive designs while addressing pressing economic, social, and environmental challenges, offering new inspiration for global small-scale housing solutions.



Fig. 25. The 8th MICROHOME Kingspan Edition 2024/25 competition cover. *Source:*
<https://architecturecompetitions.com/kingspanmicrohome2025/>

3.2.2 Unique Advantages

The competition presents several unique advantages:

1. Open Site Selection:

Designers have the freedom to envision the microhome in any geographical location, whether urban or rural. This flexibility provides ample opportunities for AI to contribute to the design process, such as through online searches, brainstorming, and accessing the latest literature and research.

2. Global Perspective:

Solutions are expected to address universal challenges while considering cultural, economic, and environmental differences. However, there are no specific requirements to focus on a particular aspect of these challenges. This conceptual nature allows both designers and AI greater creative freedom. Unlike designers who are often constrained by their expertise and experience, AI's capabilities can offer broader and more global perspectives.

3. Demand for Expertise and Challenges:

The competition requires designs to achieve comfort and livability within extremely small spaces while encouraging the innovative use of cutting-edge technologies and materials and maintaining high sustainability standards. These requirements are highly

specialized, making the competition an ideal platform to explore AI's capacity to provide professional knowledge and solutions.

4. Integration of Urban and Architectural Themes:

Last but not least, this competition addresses both urban and architectural design issues, which is a key reason it was selected as the focus of this thesis.

3.2.3 How to apply AI in competition

The fast growth of AI technology shows its great potential in design processes. For example, AI tools can combine knowledge resources, making it easier for students and professionals to access design expertise. AI can also improve traditional design workflows, enhance "computer-aided design" capabilities, and reduce wasted time and effort. In the conceptual design phase, AI can quickly test design ideas, break fixed thinking patterns, and provide objective support for more controlled and evaluable designs. Additionally, AI can generate a lot of inspiration, freeing designers from repetitive tasks so they can focus on creativity. This can improve efficiency and innovation in the industry.

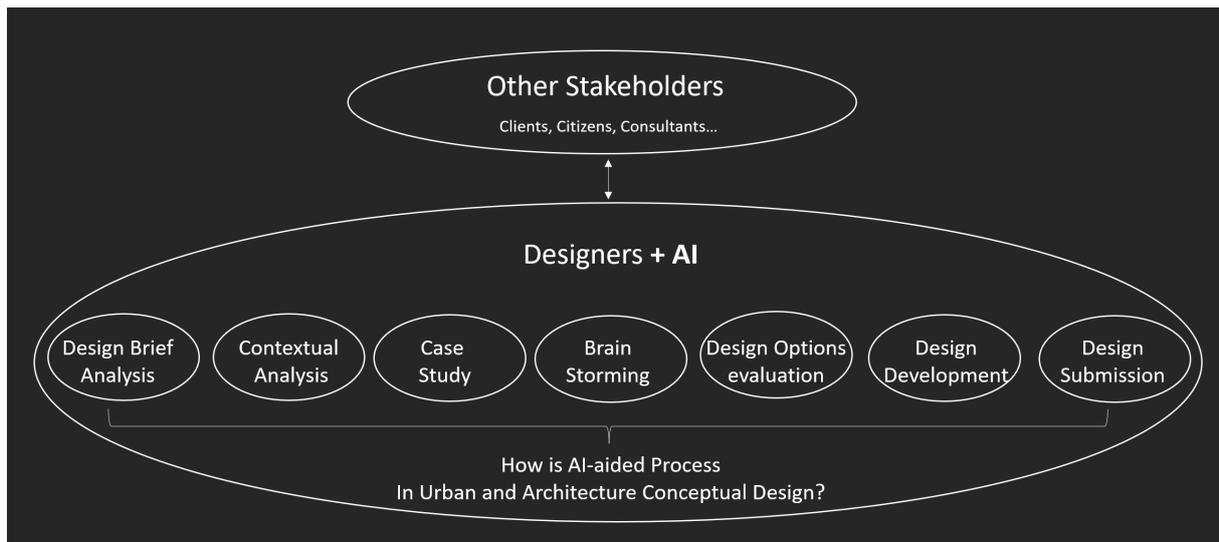


Fig. 26. How AI is applied to the traditional conceptual design process. *Source: Done by author.*

Specifically, AI can help handle repetitive tasks and help designers access information more efficiently. For example, in competitions, there is often a lot of literature to read. Useful design information is usually hidden in large amounts of text, which takes a lot of time and effort to find. Also, the research process in design often takes a lot of time. Less experienced designers may get lost in too much information and miss the key points. AI's strong search and filtering abilities can help improve this.

Besides text, AI can also create different types of information to help designers share ideas. For example, there are now many advanced image-generation tools, such as DALL-E, Mid-Journey, and Stable Diffusion. These tools can reduce the effort designers spend on visualizing

ideas in traditional workflows. They can even be used as the final way to present conceptual designs. AI can also help visualize the development and iteration of design ideas.

In addition, AI can help provide inspiration and support brainstorming in design. Current AI tools can gather and organize information to answer human questions in a systematic way. By inputting design conditions, AI can share its own ideas as a reference for designers, sparking more creativity. This process can be shown through text, images, or even videos.

In the following two chapters, this competition will be used as a case study to explore how AI is applied in urban and architectural design. It will address the questions raised at the beginning of this section.

Chapter 04: ChatGPT Applied on Urban Design and Research- from Competition Understanding to Design Strategy

Before AI, design teams handled every stage of a project by themselves. They researched competitions, selected topics, brainstormed ideas, developed concepts, and refined designs. These tasks required significant time, and relied on designers' knowledge and experience.

This thesis explores how AI supports these design stages. It focuses on two main phases: urban research and design, followed by architectural design within a selected competition. The AI tools used in this study include ChatGPT and its integrated DALL·E.

ChatGPT is widely recognized for its capabilities. Many see it as a new gateway to knowledge, with the potential to replace traditional search engines, especially among younger users (Kim et al., 2024). However, it also faces criticism. In education, concerns about ethical issues, data security, and misinformation remain. Research shows that generative AI is becoming a key part of various fields, including design. As AI grows, recognizing AI-generated misinformation is an essential skill for students (Day, 2023).

This chapter aims to explore ChatGPT's role in design practice. It evaluates its impact on the design process and examines how to maximize its potential through practical use and critical assessment.

4.1 ChatGPT and Workflow Introduction

4.1.1 What is ChatGPT

ChatGPT is an AI chatbot based on a large language model (LLM) developed by OpenAI. This section uses ChatGPT 4.0. It processes large datasets and applies deep learning to understand complex queries, interpret context, and generate relevant responses. Its ability to grasp language semantics allows it to provide accurate and insightful information, making it a useful tool for users in various fields (Haman, Školník, 2023). Since its launch in November 2022, ChatGPT has been applied in creative writing, coding, translation, syllabus design, engineering, education, and information retrieval (Kim et al., 2024).

In specialized fields like medicine and law, ChatGPT has shown professional-level performance. Studies found it scored near the **60% passing threshold** on the United States Medical Licensing Exam, achieving this without specific human training (Kung et al., 2023).

In urban and social fields, researchers have utilized ChatGPT to generate code for thematic map creation, designing new workflows, that significantly improve mapping efficiency (Tao, Xu, 2023). Other studies examined ChatGPT's performance in addressing environmental justice issues, highlighting its strengths in general analysis but weaknesses in providing localized information, due to geographic biases, emphasizing the need for fairness in data (Kim et al., 2024).

In urban planning and design, pre-trained language models (PLMs) like ChatGPT enhance research efficiency. They support policy analysis, spatial identification, and public engagement. However, challenges remain, including data limitations, social bias, and privacy concerns. Developing models with greater transparency and ethical safeguards is necessary (Sanchez et al., 2024). Research analyzing keywords from 744 academic papers showed that ChatGPT improved data processing efficiency and thematic accuracy. It reduced manual bias, demonstrating its potential in urban science (Sanchez et al., 2024). Future advancements in these models could provide even more precise and efficient tools for urban research and design.

4.1.2 Why ChatGPT

Despite its many advantages, GPT has notable limitations. It is a relatively new model with evolving capabilities. Large language models (LLMs) generate high-quality text based on prompts, but they are prone to "hallucinations" that can produce misleading information (Wu et al., 2023). Bias in training data and the learning process also raises concerns (Cotton et al., 2023). Other challenges include geographic bias, the risk of reinforcing inequality, and difficulty handling complex tasks. Why, then, was it chosen as the subject of this study?

This study examines GPT's role in competition topic selection, site analysis, and design strategy development. These tasks are open-ended, making them suitable for language-based

AI like ChatGPT. While inaccuracies and biases exist, designers can mitigate them with their expertise and further research. At the same time, ChatGPT's ability to process literature, search urban data, and integrate analysis provides strong support for designers exploring AI in urban research and design.

Although GPT is a language-based AI, its vast data sources allow it to suggest design concepts and strategies. These suggestions may seem accurate but require evaluation by designers or students. Still, its open-ended outputs inspire diverse design approaches. Human-AI interaction further enhances the creative process. With DALL·E's image generation, ChatGPT can visually present synthesized design strategies, making AI-driven design more exploratory and inspirational.

ChatGPT has also evolved quickly since its launch. It has reached a certain level of maturity and incorporates extensive data sources. Compared to other generative AI tools, it offers strong usability and reliability. With continued advancements in technology, data filtering, and integration, it is expected to play a bigger role in design. Research on AI collaboration in urban design remains limited, making ChatGPT a relevant subject for this study.

4.1.3 How ChatGPT Assist Design Workflow

ChatGPT is built on pre-trained language models and improves through techniques like contextual learning, self-learning, chain-of-thought prompting, instruction fine-tuning, and reinforcement learning from human feedback (Wu et al., 2023). Its training data includes publicly available sources such as news articles, blogs, Wikipedia, forums, books, academic papers, code repositories, and technical documentation. User interactions also contribute to model updates.

The version tested here, ChatGPT 4.0, was trained on data up to September 2023. However, it can retrieve real-time information through web search, allowing it to provide updated content.

ChatGPT has limitations, including the "hallucination problem," where responses may contain factual errors due to noise in the training data. The "black box" nature of deep learning makes it difficult to explain why these errors occur. Although content filtering reduces bias and inappropriate material, it cannot fully eliminate these issues.

When using ChatGPT as a research or design tool, it is essential to review and refine its outputs. Researchers and designers must critically evaluate AI-generated content for accuracy and reliability. Cross-referencing information with authoritative sources, industry standards, and real-world case studies ensures meaningful insights. Personal expertise, logical reasoning, and consulting professionals help address gaps in AI's contextual understanding.

Beyond text-based interactions, exploring other AI tools enhances research and design processes. Document analysis tools extract key information, image generation tools create rapid visualizations, and image analysis tools help interpret spatial relationships. Web retrieval

provides access to the latest developments. Combining these tools increases efficiency, expands creativity, and maximizes AI’s potential in design.

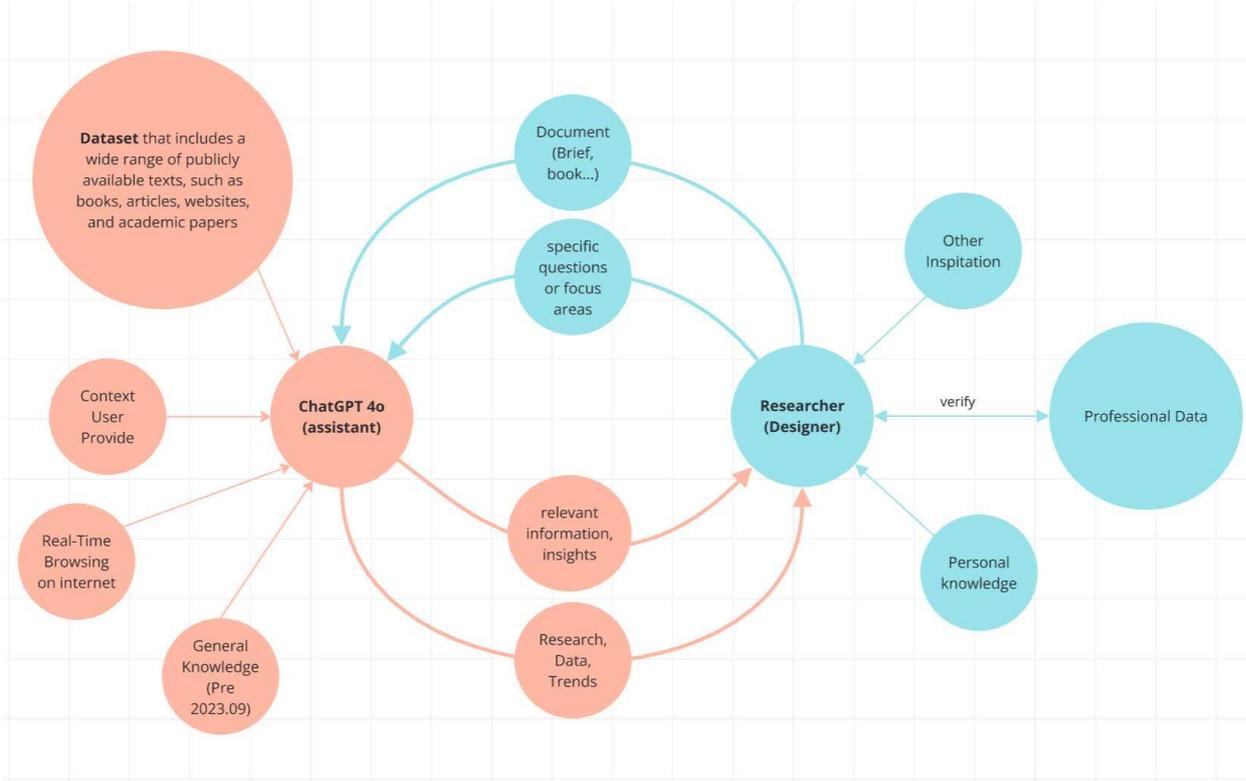


Fig. 27. ChatGPT as assistant workflow. *Source: Done by author.*

Researchers and designers evaluating ChatGPT’s role in design should maintain a fair and objective perspective. It is important to assess both its benefits and limitations. This includes measuring efficiency, content accuracy, and creative assistance while also recognizing potential issues.

A thorough understanding of ChatGPT’s strengths and weaknesses allows for a more scientific and balanced integration into the design process. This prevents biased evaluations that could affect fairness and accuracy or create overreliance on AI.

4.2 ChatGPT on Competition Understanding

4.2.1 ChatGPT on Documentation Understanding

Nearly every competition includes extensive documentation, making text interpretation a time-consuming task for urban design researchers. The design process also involves handling large amounts of textual data. Traditional methods rely on manual text analysis to interpret, summarize, and annotate key points. Even if one team member thoroughly understands the brief and shares it with others, this can lead to biases, partial understanding, and a complex, energy-draining process.

Testing AI's ability to interpret text has significant research value. As a pre-trained language model (PLM), ChatGPT excels in document analysis, text classification, and generation, improving how researchers interact with competition materials (Fu et al. 2024). For complex texts, AI can replace tedious manual analysis, reduce labor costs, and improve accuracy in urban research.

Given the importance of understanding competition briefs in the early stages of a competition, this study selected the <MICROHOME Kingspan 2025 Competition Brief> as a case study. The document, uploaded to ChatGPT with specific prompts, contains about 13,000 words, 20 images, 28 pages, and is 6 MB in size. Two groups were set up to compare human and AI performance in interpreting content, ensuring accuracy, and identifying key points.

The control group included four students with 7 to 10 years of academic or practical experience. On average, three researchers took 10 minutes for an initial read-through and 55 minutes to fully understand and summarize the key points.

In contrast, ChatGPT processed and "understood" the document in about 7 seconds and generated a full analysis in 15 seconds, making it roughly **200 times faster** than the designers. Since its responses were directly based on the competition brief, ChatGPT's accuracy showed no significant deviations.

However, I found certain shortcomings in ChatGPT's responses. While detailed, they were sometimes redundant and missed key design elements. For example, the brief clearly outlined design and construction guidelines in a concise table, highlighting that the final residential solution should be "**Cost-effective**," "**Environmentally responsible**," and "**Energy-efficient**," with detailed explanations. Designers can study these points carefully to find potential breakthroughs for winning the competition.

In contrast, ChatGPT provided an accurate summary of the competition but mixed these critical points with other design considerations. This suggests that while AI is efficient, it currently lacks the human ability to spot innovative aspects and key opportunities in competition briefs, which depend on experience and professional insight.

Table 1 ChatGPT for documentation understanding (generated on 2, December, 2024)

Prompt 1	Please read and understand this document from a competition, give back the main points of it. (Also attached the brief of the competition <MICROHOME Kingspan 2025 Competition Brief> as pdf. format)
ChatGPT answer 1	<p>Here are the main points of the Kingspan 2024/25 Microhome Architecture Competition:</p> <p>Purpose and Theme</p> <ul style="list-style-type: none"> •The competition focuses on designing an off-grid modular dwelling for a young professional couple within a maximum area of 25 m². •Participants are encouraged to explore sustainability, innovative design, and affordability. •Designs should address economic, social, and cultural challenges while being environmentally responsible and cost-effective. <p>Design Considerations</p> <ul style="list-style-type: none"> •The project must incorporate: <ul style="list-style-type: none"> • Sleeping, living/working, cooking areas, and a WC/shower. • Proposals should include energy-efficient solutions like renewable energy systems, water management, and waste strategies. •Considerations include: <ul style="list-style-type: none"> • Community integration to encourage social interaction. • Adaptability for diverse contexts and scalability for broader applications. • Educational value to promote sustainable living. <p>Site and Flexibility</p> <ul style="list-style-type: none"> •The site can be urban or rural, with no specific geographical restrictions, allowing freedom in location selection. •Landscape elements and auxiliary structures (like terraces) are excluded from the 25 m² footprint. <p>Prizes and Awards.....</p> <p>Kingspan Award.....</p> <p>Submission Requirements.....</p> <p>Publicity and Media Exposure.....</p> <p>Eligibility.....</p> <p>Let me know if you'd like a deeper analysis of any specific aspect!</p>

Nevertheless, AI's ability to quickly grasp the most important and core information provides significant assistance and holds promise for improving traditional text interpretation processes. When designers manually summarize competition briefs, their focus often varies depending on individual experiences and interests. In contrast, AI can objectively and impartially interpret and summarize texts, helping teams achieve clearer consensus or offering a foundational basis for discussion.

An ideal workflow would involve AI rapidly understanding and summarizing the text, followed by a designer reviewing, verifying, and refining the AI-generated content to extract key points for communication with team members. This approach not only reduces errors in document comprehension but also enhances team efficiency.

Overall, AI shows great potential in text interpretation, offering both **accuracy and efficiency**. Natural language models like ChatGPT can quickly summarize large texts and extract key information for designers. They also enable smooth interaction through natural language, streamlining the design process and enhancing collaboration.

4.2.2 ChatGPT on User Understanding

This study identifies the target users as young professionals seeking a better life through microhome designs. Given AI's innovative and open-minded nature, this section tests ChatGPT's ability to understand user needs and interpret competition briefs. Based on past competitions and expert insights, Shanghai was chosen as a modern urban setting. Relevant urban and social issues were also considered.

AI's text classification and integration capabilities can enhance public participation in urban design. It can analyze sentiment, helping researchers quickly capture public feedback on urban systems and understand key policy needs (Karduni and Sauda, 2020). Furthermore, it allows policymakers to comprehend the deeper reasons for public support or opposition to urban systems (Luo et al., 2019).

By integrating ChatGPT's web-based information processing and language comprehension, AI can efficiently analyze public opinions on urban design and policies, reducing bias and improving accuracy. In the future, these advancements could lead to more precise and inclusive urban planning and decision-making.

Since ChatGPT's training data comes mostly from internet sources, often created by individuals similar to this study's user group, it has the potential to provide answers that align with their social needs. However, due to the "**black-box**" nature of AI, the exact sources of its responses cannot be traced. Instead, this study evaluates the quality and relevance of ChatGPT's answers through analysis and assessment.

Table 2 ChatGPT for User’s understanding (generated on 2, December, 2024)

Prompt 2	Answer 10 urban or social issues, the user- young professional couple is facing, in large cities like Shanghai.
ChatGPT answer 2	<p>Here are 10 urban and social issues that a young professional couple might face in large cities like Shanghai:</p> <ol style="list-style-type: none"> 1.Housing Affordability High property prices and rental costs make it challenging for young couples to find suitable and affordable housing close to work or essential amenities. 2.Space Constraints Limited living space in densely populated cities restricts comfort and lifestyle choices, often forcing couples to compromise on their living arrangements. 3.Work-Life Balance Long working hours and demanding jobs in fast-paced urban environments leave little time for personal relationships and leisure activities. 4.Commute Challenges Heavy traffic and overcrowded public transport lead to lengthy, stressful commutes, reducing time spent at home or on personal pursuits. 5.Air Pollution Poor air quality in large cities like Shanghai negatively affects health and overall well-being, adding to stress and medical concerns. 6.Cost of Living The high cost of goods, services, and utilities, combined with stagnant wage growth, limits savings and financial stability for young couples. 7.Social Isolation Despite living in densely populated cities, the fast-paced lifestyle and lack of community spaces often lead to feelings of isolation and detachment from neighbors or local communities. 8.Family Planning and Childcare Planning for a family is challenging due to the high cost of childcare, limited availability of quality education, and the pressure to secure resources for raising children. 9.Urban Noise and Overcrowding Constant exposure to noise pollution and overcrowded environments creates mental fatigue and reduces the quality of life. 10.Access to Green Spaces Limited access to parks and recreational areas makes it difficult for young couples to enjoy outdoor activities and maintain physical and mental health. <p>Would you like detailed suggestions for addressing these issues in the context of a microhome design?</p>

ChatGPT’s responses effectively captured the social needs of the target user group and urban issues. It prioritized widely discussed topics, aligning well with societal demands. Through literature review and interviews with users in Shanghai, we found that many AI-generated points—especially 1, 2, and 3—were widely recognized. Additionally, points 4, 6, 8, and 9 were frequently mentioned, while 9 and 10, though less discussed in interviews, were still validated. However, point 7 was neither widely accepted nor recognized, facing some skepticism.

The AI-identified user needs closely align with broader urban issues, making them valuable entry points for competition-related design research. Notably, points 5, 9, and 10 emphasized environmental concerns, reflecting the competition’s sustainability principles. This alignment may be influenced by the competition brief being input into the AI, shaping its focus and responses.

In conclusion, ChatGPT effectively completed the user analysis. Despite the open-ended questions, its responses were **efficient, practical, and comprehensive enough** to serve as strong starting points for competition-related design exploration.

4.3 ChatGPT on Urban Issue Research and Site Finding

4.3.1 Design issue research

This section continues to evaluate ChatGPT's ability to assist in divergent thinking for design by testing its capacity to identify entry points for urban issue competitions. The purpose of this test is not to find the most broadly discussed urban issues, but to identify those that are suitable as competition entry points—issues that can inspire and drive innovative design ideas.

Table 3.a ChatGPT on Urban and architectural Issues finding for competition
(generated on 2, December, 2024)

Prompt 3	Answer 10 urban and building challenges in Shanghai:
ChatGPT answer 3	<p>Here are 10 urban and building challenges in Shanghai:</p> <p>Urban Challenges</p> <ol style="list-style-type: none"> 1.Overcrowding in Central Areas High population density in key districts like Huangpu, Jing'an, and Xuhui places significant pressure on infrastructure, public transport, and public services. 2.Traffic Congestion Despite a well-developed metro system, road traffic congestion continues to be a major issue, particularly during peak hours, causing long commute times and pollution. 3.High Housing Costs Skyrocketing property prices and high rents make housing unaffordable for many residents, particularly young professionals and lower-income families. 4.Limited Green Spaces While Shanghai has many parks, the rapid urbanization means that green spaces are increasingly limited, reducing recreational areas and contributing to the urban heat island effect. 5.Pollution Air and water pollution remain critical issues, with particulate matter (PM2.5) from vehicles, industry, and construction affecting public health and the environment. <p>Building Challenges</p> <ol style="list-style-type: none"> 6.Aging High-Rises Many older residential and commercial high-rises built in the 1980s and 1990s suffer from structural wear, outdated safety standards, and energy inefficiency, requiring costly maintenance and retrofitting. 7.Insufficient Building Insulation Many older buildings lack adequate insulation, leading to high energy consumption for heating and cooling and contributing to excessive energy costs and carbon emissions. 8.Lack of Accessibility in Older Buildings Older buildings, particularly in historic districts, often lack elevators, ramps, and other features that make them accessible with disabilities or the elderly. 9.Urban Sprawl The outward expansion of the city into suburban areas creates challenges such as the inadequate infrastructure in newly developed districts, long commuting times, and the difficulty in integrating new developments into the existing urban fabric. 10.Inefficient Land Use Inefficient land use due to poorly planned zoning and the separation of residential, commercial, and industrial areas leads to congestion, increased commuting distances, and underutilized spaces in some districts. <p>These challenges can be addressed through urban renewal projects, better planning, and a focus on sustainability in new and retrofitted buildings. Would you like to discuss possible solutions for any of these?</p>

Table 3.b ChatGPT on Urban and architectural Issues finding for competition
(generated on 2, December, 2024)

Prompt 4	This is interesting. I realized that the point 1,2,4, 6,10 you mentioned, is all related with the Topic of highrise (especially the over development of office tower) in city center. Could you give another 10 points about this topic related with this issue
ChatGPT answer 4	<p>You're absolutely right! The overdevelopment of office towers and the associated urban challenges in city centers is a major issue in Shanghai. Here are 10 more points related to the overdevelopment of office towers in city centers, particularly regarding high-rise buildings:</p> <p>Urban Challenges</p> <ol style="list-style-type: none"> 1.Shadowing and Reduced Natural Light The overabundance of office towers can lead to excessive shadowing, limiting natural light for surrounding buildings and streets, negatively affecting the urban experience. 2.Displacement of Residential Spaces The conversion of residential areas into commercial spaces or high-rise office towers leads to the loss of housing units, exacerbating the affordability crisis in the city center. 3.Lack of Human Scale High-rise office towers can create a feeling of disconnection from the ground level, making the streets feel cold and unwelcoming, reducing pedestrian engagement and community interaction. 4.Increase in Urban Heat Island Effect Large clusters of office towers in the city center absorb and trap heat, contributing to rising temperatures and making the city less comfortable, especially in the summer months. 5.Over-saturation of Office Space An oversupply of office towers in prime locations leads to underutilized spaces and reduces the potential for other forms of development, such as mixed-use buildings or affordable housing. <p>Building Challenges</p> <ol style="list-style-type: none"> 6.High Maintenance and Operational Costs The maintenance and operation of high-rise office buildings are expensive, including the upkeep of elevators, HVAC systems, and structural elements, which are difficult to manage over time in aging buildings. 7.Traffic and Pedestrian Congestion The concentration of office towers in city centers increases traffic congestion, particularly during office hours, and leads to overcrowding on streets and public transport systems. 8.Limited Green and Recreational Spaces The overwhelming number of office towers often leads to a lack of green spaces, parks, or recreational areas in the central business district, further reducing livability for residents and workers. 9.Construction-Related Disruptions The constant construction of new high-rise office buildings leads to noise, dust, and traffic disruptions, affecting both workers and local residents, and contributing to the overall urban stress. 10.Environmental Impact of Construction The environmental footprint of building office towers (including resource consumption, energy use, and waste generation) is significant. It contributes to carbon emissions and the depletion of local resources, making urban development unsustainable if not addressed through green building initiatives. <p>These challenges highlight the need for balanced urban development that integrates office, residential, and recreational spaces, as well as sustainable building practices. Solutions like mixed-use developments, green architecture, and better zoning regulations can help mitigate some of these issues. Would you like to explore potential strategies or examples for tackling these challenges?</p>

Given the high efficiency of AI's responses, researchers interacted with ChatGPT to refine its initial answers by offering feedback and corrections based on their design expertise. It's important that researchers maintain professional phrasing when guiding the AI.

Upon validation, ChatGPT's response to **Prompt 3** was generally accurate but lacked innovation and was too broad. To improve this, researchers selected more relevant points and provided targeted feedback and further instructions in **Prompt 4**.

Ultimately, due to the open-ended nature of the question, ChatGPT's responses in this round did not gain as much widespread recognition as in the previous section. Many answers were overly "common-sense-based" and lacked theoretical depth. Some topics, although valid, were not universally applicable. Most answers were broad and did not offer direct inspiration to researchers. Subsequent targeted prompts often resulted in repetitive and redundant answers, potentially hindering researchers' active and open-ended thinking.

However, ChatGPT does highlight certain urban issues that are often overlooked and brings innovative perspectives, particularly in **point 5**. Based on this, the researchers reviewed relevant materials and found that in megacities like Shanghai, while the skyline is dominated by numerous modern high-rise buildings, there is indeed a phenomenon of vacant office spaces in tall buildings. This issue, however, deserves more attention and further research.

Given the timeliness of this issue, the researchers guided ChatGPT to search the internet for the latest professional research reports. Within a short period, ChatGPT identified five reports. After careful verification, all five reports were found to originate from leading global real estate services or professional investment management companies.

However, ChatGPT currently lacks advanced capabilities for integrating and managing webpage links effectively. Among the five reports, only the link to **report 3** could be directly accessed through the answer provided by ChatGPT, while the other links were not directly accessible.

Table 3.c ChatGPT on Urban and architectural Issues finding for competition
(generated on 2, December, 2024)

Prompt 5	The point 5 (over-saturation of Office space) has a good potential to be the starting point of the competition. Could you find some related resource online about the report of Office vacant or over-saturation situation in Shanghai, and give some original link(url.) for my review.
ChatGPT answer 5	<p>Here are some online resources with reports on office vacancy and oversaturation in Shanghai, which could serve as useful references for your competition:</p> <ol style="list-style-type: none"> 1. Colliers International - Shanghai Office Market Report Colliers' reports regularly cover the office vacancy situation in Shanghai, identifying trends in the supply and demand of office spaces, vacancy rates, and market forecasts. Link: Colliers Shanghai Office Market Report 2. CBRE - Shanghai Office Market Overview CBRE provides insights into Shanghai's office market, discussing vacancy rates and market trends, with special focus on the oversupply of office space and evolving tenant demands. Link: CBRE Shanghai Office Market Overview 3. Knight Frank - Shanghai Office Market Insights Knight Frank's quarterly reports on Shanghai's office market address key issues like oversupply of office space, vacancy rates, and rental trends, offering in-depth analysis and projections for the market. Link: Knight Frank Shanghai Office Market Insights 4. JLL - Shanghai Office Market Analysis JLL's reports provide data on vacancy rates in Shanghai's office sector, exploring the market's response to oversupply, trends in office demand, and evolving tenant preferences. Link: JLL Shanghai Office Market Analysis 5. Savills - Shanghai Office Market Overview Savills offers a comprehensive review of Shanghai's office market, including vacancy and oversupply concerns, market forecasts, and sector-specific trends. Link: Savills Shanghai Office Market Overview <p>These resources will provide you with valuable insights into the current vacancy rates, oversaturation issues, and market dynamics in Shanghai's office space sector. Would you like help synthesizing these findings for your competition proposal?</p>

Compared to traditional search engines, ChatGPT provided a faster way to identify and filter professional research, assisting designers in market analysis. Studies from several professional institutions indicate that in megacities like Shanghai, the vacancy rate of Grade A office buildings has reached around 20% in recent years (2019–2024), with downward pressure on rents (Sheng and Chio 2024). However, ChatGPT's responses are not guaranteed to be complete or fully reliable and require further verification.

When generating design concepts and inspiration, ChatGPT tends to give cautious and broad answers. Repeated testing often leads to similar responses, but with more professional and targeted prompts, outputs can be refined. At the same time, AI's responses remain unpredictable to some extent.

While interactions with ChatGPT may sometimes lack focus, produce low-quality answers, or require extra effort, which could slow active idea exploration, the overall results show that through testing, verification, and reflection, researchers successfully used AI to identify urban issues with potential for design competitions.

4.3.2 Site finding

After selecting the design topic, traditional urban site research and selection typically rely on search engines or professional urban information websites. However, due to the novelty of this topic and the sensitivity of office vacancy data, obtaining accurate information and choosing a competition site presents challenges.

Currently, no specialized urban design or planning websites provide specific market data on vacant office buildings. Most available resources are research reports that focus on broader district-level analyses rather than individual plots.

Using traditional search engines like Google or Baidu to find suitable sites in Shanghai is time-consuming and difficult. Results are often buried under irrelevant content, advertisements, or fragmented information, requiring additional verification. Even when data is available, it lacks a comprehensive perspective.

Since ChatGPT’s training data is largely sourced from the internet, it offers an advantage over traditional search engines by streamlining the search process and reducing labor costs. Using ChatGPT, we identified potential sites for the design project. After multiple prompts and filtering out irrelevant or incorrect responses, ChatGPT summarized five potential vacant office building sites (**Table 4**).

Table 4 ChatGPT assist on project finding (generated on 2, December, 2024)

Prompt 6 (some separated questions)	<p>Could you find me is there is any super high-rise building in Pudong, Shanghai has the vacant rent issue?</p> <p>The last two are better, could you find me more specific building?</p> <p>could you find me a specific urban plot facing high vacant rate in shanghai, like lujiazui or northbund?</p> <p>could you organize all the buildings you provide to a form?</p>																														
ChatGPT answer 6	<table border="1"> <thead> <tr> <th data-bbox="411 1420 596 1458">Building Name</th> <th data-bbox="612 1420 746 1458">Location</th> <th data-bbox="762 1388 896 1458">Gross Floor Area (sqm)</th> <th data-bbox="912 1388 1046 1458">Vacancy Rate</th> <th data-bbox="1062 1420 1197 1458">Notes</th> </tr> </thead> <tbody> <tr> <td data-bbox="411 1469 580 1491">Super Brand Mall</td> <td data-bbox="612 1469 699 1559">Lujiazui Financial District</td> <td data-bbox="762 1469 820 1491">N/A</td> <td data-bbox="912 1469 970 1491">34%</td> <td data-bbox="1062 1469 1318 1525">Facing oversupply issues in retail space.</td> </tr> <tr> <td data-bbox="411 1581 564 1603">DBS Bank Tower</td> <td data-bbox="612 1581 699 1671">Lujiazui Financial District</td> <td data-bbox="762 1581 836 1603">72,044</td> <td data-bbox="912 1581 1031 1671">High Vacancy, To Be Sold</td> <td data-bbox="1062 1581 1302 1637">Part of the Lujiazui Group portfolio.</td> </tr> <tr> <td data-bbox="411 1693 564 1749">Lujiazui Century Financial Plaza</td> <td data-bbox="612 1693 699 1783">Lujiazui Financial District</td> <td data-bbox="762 1693 836 1715">312,000</td> <td data-bbox="912 1693 1031 1783">High Vacancy, To Be Sold</td> <td data-bbox="1062 1693 1270 1715">Five-building complex.</td> </tr> <tr> <td data-bbox="411 1805 517 1827">Fuhui Plaza</td> <td data-bbox="612 1805 699 1895">Lujiazui Financial District</td> <td data-bbox="762 1805 836 1827">31,977</td> <td data-bbox="912 1805 986 1850">High Vacancy</td> <td data-bbox="1062 1805 1334 1861">Part of a larger asset sale by Lujiazui Group.</td> </tr> <tr> <td data-bbox="411 1906 580 1984">Lujiazui Financial Holding Plaza (金控广场)</td> <td data-bbox="612 1906 699 1995">Lujiazui Financial District</td> <td data-bbox="762 1906 836 1928">115,000</td> <td data-bbox="912 1906 1031 1995">High Vacancy, To Be Sold</td> <td data-bbox="1062 1906 1350 1984">A major office building in Lujiazui, facing vacancy challenges due to oversupply.</td> </tr> </tbody> </table>	Building Name	Location	Gross Floor Area (sqm)	Vacancy Rate	Notes	Super Brand Mall	Lujiazui Financial District	N/A	34%	Facing oversupply issues in retail space.	DBS Bank Tower	Lujiazui Financial District	72,044	High Vacancy, To Be Sold	Part of the Lujiazui Group portfolio.	Lujiazui Century Financial Plaza	Lujiazui Financial District	312,000	High Vacancy, To Be Sold	Five-building complex.	Fuhui Plaza	Lujiazui Financial District	31,977	High Vacancy	Part of a larger asset sale by Lujiazui Group.	Lujiazui Financial Holding Plaza (金控广场)	Lujiazui Financial District	115,000	High Vacancy, To Be Sold	A major office building in Lujiazui, facing vacancy challenges due to oversupply.
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Upon verification, all five sites identified by ChatGPT exist and face vacancy issues. While some site areas could not be confirmed, the remaining details were verified through reliable links provided by AI or materials from site owners. However, ChatGPT's classification of these sites as having "high vacancy" could not be directly validated—only their "to be sold" status was confirmed. This highlights a key limitation: if left unverified, AI-generated qualitative inferences may cause misunderstandings.

This round of responses also showed that AI does not fully understand human design intentions. Researchers must carefully refine their prompts to help ChatGPT grasp requirements more accurately. For example, two of the five sites (1 and 4) were vacant shopping malls, which are irrelevant to the focus on vacant office spaces. Unlike human researchers, who can actively filter out redundant information, AI lacks initiative in understanding design intent.

Despite these limitations, ChatGPT proved useful in identifying potential design sites, especially given the lack of reliable online data and the inability of traditional search tools to provide sufficient support. After filtering AI's responses and conducting further investigation, **Site 3** – Lujiazui Century Financial Plaza was found to have strong potential as a competition location.

However, AI-generated responses sometimes appeared accurate while containing **errors** or irrelevant details, making critical thinking essential for researchers. Additionally, maximizing AI's effectiveness requires carefully **crafted and standardized prompts** to ensure more accurate and relevant results.

4.4 Urban Design Strategy- from Brain Storm to Visualization

4.4.1 Design Brain Storm and Image Understanding

Similar to the previous section, where AI explored design topics, this section uses AI to assist researchers in brainstorming creative ideas. However, unlike before, this process incorporates competition-related design requirements into the prompts. Since ChatGPT refines its answers based on feedback, we also considered the viability of ideas when evaluating its responses. This approach tests whether ChatGPT can propose open-ended yet professional design concepts under more structured conditions.

Unlike traditional design methods, which often follow a designer's predefined thinking patterns, this study **starts with real user needs** and uses AI to generate design proposals as a foundation. The prompts integrate relevant user demands identified in previous chapters to guide AI's responses.

In traditional methods, designers' own knowledge and experience often shape the starting points, which can create a disconnect from actual user needs or real-world problems. This may lead to narrow or overly self-satisfied designs from the outset. This also highlights the importance of brainstorming in the design process, where participants can inspire, critique, and expand ideas to encourage open and diverse thinking.

Table 5 ChatGPT assist on design brain storm (generated on 2, December, 2024)

Prompt 7	Good, I believe that the transformation of some vacant highrise volumn in the city center of Shanghai to dwelling house could be a solution to solve some the urban and social issue. Base on these condition, Competition topic: off-grid modular dwelling, a young professional couple, within a maximum area of 25 m ² User Issue I picked: Housing Affordability, Commute Challenges, Social Isolation, Access to Green Spaces give me 10 ideas as direction to do the design for the competition.
ChatGPT answer 7	<p>Here are 10 design direction ideas for your competition, based on the transformation of vacant high-rise volumes in the city center of Shanghai to off-grid modular dwellings for a young professional couple:</p> <ol style="list-style-type: none"> 1. Modular, Stackable Units Design the dwelling as stackable modular units that can be easily assembled within the vacant volumes of high-rise buildings. These units should be self-contained, with off-grid systems like solar panels and rainwater collection, making them adaptable and scalable as needed. 2. Flexible Layout with Sliding Walls Use sliding or folding walls to create a flexible layout within the 25 m² space. This allows the young couple to open or close areas as needed, transforming the unit from a living room to a home office or bedroom, maximizing the use of the small space. 3. Integrated Green Spaces Incorporate vertical gardens, plant walls, or indoor green spaces into the design to improve air quality and provide a calming, natural environment. This directly addresses the lack of green spaces in urban centers and enhances the overall well-being of the couple. 4. Shared Communal Spaces Create shared communal spaces within the building, such as co-working spaces, lounges, and shared kitchens. These spaces would foster social interaction, reduce feelings of isolation, and help build a sense of community among residents in the high-rise. 5. Green Roofs and Rooftop Gardens Utilize the roof of the high-rise to create a shared green space or private rooftop garden. This provides access to outdoor space, relaxation areas, and opportunities for growing plants or even small-scale food production, addressing the need for green spaces in the city. 6. Sustainable Energy Systems Design the unit to be off-grid by incorporating sustainable energy systems such as solar panels, wind turbines, and rainwater harvesting. This would make the dwelling self-sufficient, reducing utility costs and contributing to housing affordability. 7. Compact, Multi-Functional Furniture Use space-saving, multi-functional furniture like folding tables, wall-mounted storage, or modular seating that transforms into beds. This design maximizes the available space while maintaining functionality and comfort, essential for small-scale living. 8. Efficient Transportation Solutions Although the unit is compact, its location should offer easy access to public transportation such as metro stations, buses, and bike-sharing systems. Consider integrating personal mobility tools, like electric bikes or compact scooters, to help address commute challenges. 9. Smart Home Integration Implement smart home technology to automate lighting, heating, and water usage. This reduces energy consumption and enhances convenience for the residents, helping to keep living costs low while improving sustainability. 10. Social and Cultural Spaces In addition to private spaces, include areas for cultural engagement such as a small gallery space or performance area where residents can host art shows, music sessions, or community gatherings. This would foster a vibrant social life and reduce social isolation. <p>These ideas aim to create a sustainable, adaptable, and community-oriented living space that addresses affordability, commute challenges, social isolation, and access to green spaces in Shanghai's high-rise urban context. Would you like to dive deeper into any of these ideas or need help with any specific aspect of the design?</p>

The results show that ChatGPT's design ideas were professional, comprehensive, and provided inspiration. Its responses included both large-scale design strategies (3, 4, 6) and practical design actions (1, 2, 5, 7, 9, 10). Apart from (8), which had operational challenges, there was little redundant or irrelevant information. While feasibility requires further evaluation, the

design concepts generated under defined conditions and based on user needs effectively supported the brainstorming process.

Beyond the **user-centered design approach**, there is also an **experience-oriented approach**, which focuses on human perception, experience, and emotion. In this context, text-generation AI can serve as a tool for early-stage brainstorming or as a starting point for design. With features like efficiency, real-time responses, precise language expression, and objective descriptions, AI tools like ChatGPT—when combined with text-to-image tools—can further inspire design ideas.

As technology advances, more objective, scientific, and efficient design methods may emerge, challenging traditional approaches based on the designer's experience and knowledge.

Additionally, when using language-based AI, designers often need to describe images in words, making the interaction between text and visuals essential. ChatGPT, as one of the most widely used and advanced language-generation AI tools, also has image understanding capabilities. To test this, we uploaded an aerial image of the selected site and asked ChatGPT to describe the image.

Table 6 ChatGPT on Image understanding (generated on 8, January, 2025)

Prompt 8	Could you understand this picture: this is a picture of the project with 5 office towers, which I selected to be the site of the design project. Describe this picture.
	
ChatGPT answer 8	<ul style="list-style-type: none">▪ This image depicts a cluster of five modern office towers in an urban environment. The buildings are arranged in a well-organized layout, surrounded by landscaped areas, roads, and nearby residential and commercial buildings. The towers have a sleek and contemporary design with a dark facade, giving them a professional and corporate appearance.▪ One unique feature visible in the image is the circular, green-roofed building in the background, standing out due to its distinct design. The towers are interconnected with landscaped pathways and open spaces, suggesting a focus on accessibility and integration with the urban context.▪ This setting seems like an ideal choice for an architectural design project, given its urban density, modern design, and potential for redevelopment or transformation into mixed-use or residential spaces. Let me know if you need further details or analysis for your project!

It can be observed that ChatGPT's description is generally objective and without error, demonstrating its ability to describe images of medium complexity. In the future, this ability possible to help the design better combine the image and text workflow with AI, to reach a more efficient workflow.

4.4.2 Design Visualization by DALL·E inside ChatGPT

DALL·E, developed by OpenAI and integrated into ChatGPT, is a text-to-image generation model that creates realistic images or artwork based on user input. It supports various styles and scenarios and is widely used in content creation, educational research, design, and game development. Designers can use it for concept designs, illustrations, and game scenes.

Built on the Transformer architecture and trained on large-scale text and image datasets, DALL·E learns the relationship between language and visuals. The latest version improves image quality and better understands complex textual descriptions, offering high-resolution outputs with great potential for early-stage exploration and inspiration in architecture and urban design.

For example, based on the selected design direction, we used DALL·E to generate conceptual diagram images, including traditional office volumes and transformed residential community volumes. After two rounds of testing, we found that DALL·E performs well in quickly creating simple design diagrams. It is beginner-friendly, helps designers make intuitive visual judgments, and serves as an effective tool for **communicating design concepts**.



(a)



Fig. 28. The concept of traditional office high rise (a) and transformed mix-used high rise (b).
Source: Done by author on DALL-E inside ChatGPT 4o.

Building on ChatGPT's proposed design strategies, we selected the most feasible ideas and used textual descriptions to guide DALL-E in generating visualizations. The design prompts were divided into two parts:

1. **Site description** – e.g., *"five towers, one site."*
2. **Refined design strategies** – e.g., *"two types of facades," "bridge connected on the top," "vivid life and green."*

This approach tested DALL-E's image generation capabilities and aimed to produce visuals that could inspire design ideas.

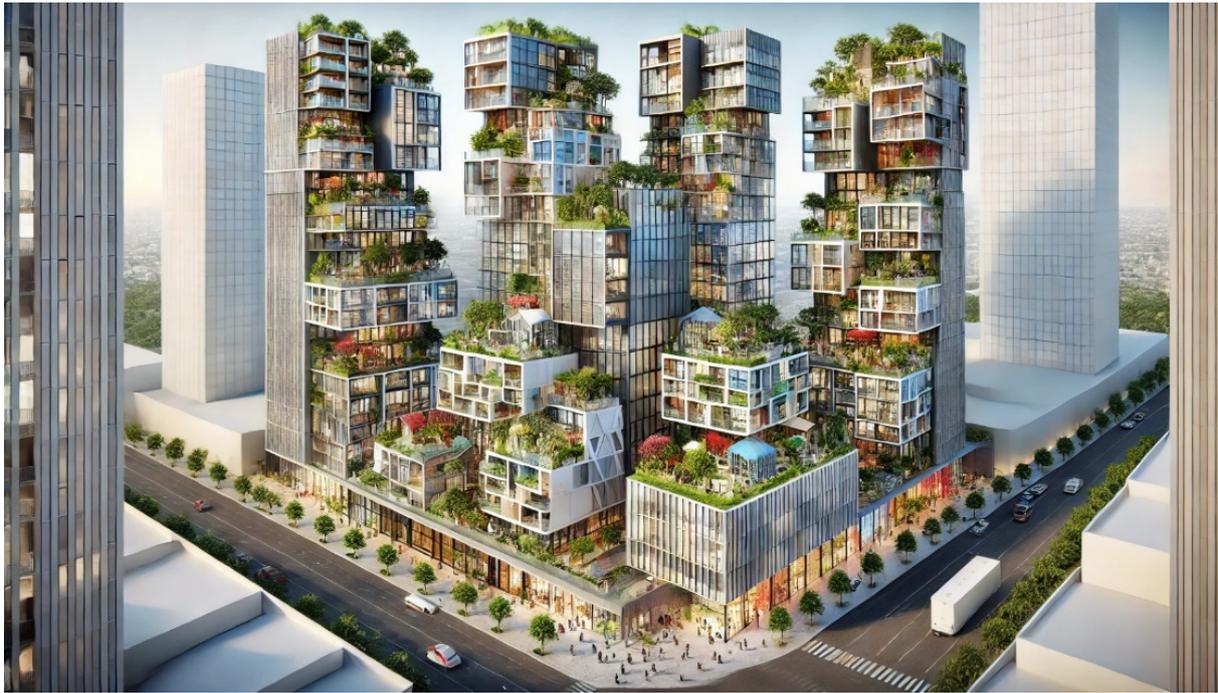


Fig. 29. Reference image high rise buildings transformed to mix-used community. *Source: Done by author on DALL·E inside ChatGPT 4o*

Image Prompt: *one urban block, five towers with two features: one is same office simple facade in the bottom, another one is residential units and facades with vivid life and green in the top, these five tower also varies in height, some bridge connected the top residential part, some bridge connected with neighbor urban plots, ground floor lots of public facilities and urban life*

AI can understand and describe images, effectively capturing key elements and conveying the design vision and atmosphere. However, current AI-generated images **lack precision** in spatial representation and proportions. Even with clear textual descriptions, such as "five towers," the final output is often inaccurate. Additionally, some details, like "bridges connected in the air," are not always reflected in the images.

Despite these limitations in control and consistency, AI-generated images still provide inspiration. They are fast, efficient, and offer intuitive visual feedback, helping designers communicate ideas. As technology advances, the integration of language-based AI and image-generation AI is expected to enhance design workflows, offering more inspiration and improving overall processes.

4.4.3 Urban Design Strategy

To test AI's ability to propose **urban design strategies** for a specific site, we gathered information about its surroundings and extracted key details to provide as text input to ChatGPT. Since the AI had previously analyzed the site and conducted preliminary research, it could build on prior responses.

These researcher-provided inputs served as guidance, helping ChatGPT generate strategies that better align with the site and competition requirements.

Table 7 ChatGPT assist on urban design brain storm(generated on 2, December, 2024)

Prompt 9	Lujiazui Century Financial Plaza is facing office high vacant issue, located on a site of Pudong district with these conditions: on the east is high density residential plot, on the south is an aged highrise hotel, and then another high deisity residential plot both seperated by third level road, on the east is some high density residential plots, while seperated by a first level road, on the north is a group of office plots, seperated by a secondary level road. Could you give 10 "URBAN ideas" to improve this plot, or better integrate with other plots surrounding.
ChatGPT answer 9	<p>Here are 10 urban design ideas to improve Lujiazui Century Financial Plaza and better integrate it with the surrounding plots:</p> <ol style="list-style-type: none"> <p>1. Mixed-Use Development with Residential Integration</p> <ul style="list-style-type: none"> •Idea: Convert vacant office floors in Lujiazui Century Financial Plaza into residential units (e.g., affordable housing or co-living spaces) to better align with the residential character of the surrounding east and south. This would introduce a live-work-play concept and reduce the commuting pressure from the surrounding high-density residential areas. •Benefit: Adds housing supply to a central district, improving the balance between commercial and residential needs in the area. <p>2. Pedestrian Bridges and Green Walkways</p> <ul style="list-style-type: none"> •Idea: Create pedestrian bridges or green walkways that connect the Lujiazui Century Financial Plaza with the high-density residential plots to the east and south. These pedestrian routes can be lined with greenery and public seating, creating a more pedestrian-friendly environment and promoting walkability. •Benefit: Encourages active transportation and social interaction by creating more convenient, pleasant routes for pedestrians, linking residential areas with commercial spaces. <p>3. Public Green Space and Plazas</p> <ul style="list-style-type: none"> •Idea: Develop a public plaza or green park in the vacant ground area or rooftops of the Lujiazui Century Financial Plaza. This could be a multi-level public space that serves both residents and workers, incorporating features like community gardens, outdoor seating, and areas for social gatherings and events. •Benefit: Increases the area’s livability, helps mitigate the urban heat island effect, and provides a space for social interaction among residents and workers. <p>4. Co-working and Flexible Office Spaces</p> <ul style="list-style-type: none"> •Idea: Repurpose part of the vacant office space for flexible office spaces or co-working hubs targeting small businesses, startups, and remote workers. These spaces would be designed to attract a new type of worker and be more adaptable to the post-pandemic work trends. •Benefit: Helps reduce the vacancy rate while integrating with the surrounding residential population, offering flexible workspaces closer to home for local residents. <p>5. Mixed-Use Commercial with Community Retail</p> <ul style="list-style-type: none"> •Idea: Integrate community retail spaces on the ground floor of Lujiazui Century Financial Plaza, offering amenities like cafes, convenience stores, fitness centers, and childcare. These services can be focused on local residents and workers, making the building more accessible and community-oriented. •Benefit: Brings essential services closer to both residents and workers, enhancing local convenience and supporting active ground-level use. <p>6. Create Active Ground Floor and Shared Spaces</p> <ul style="list-style-type: none"> •Idea: Activate the ground floor by integrating public spaces such as open-air cafes, art installations, or even pop-up retail spaces. This would create a public-facing area that invites both residents and workers to interact with the space, fostering community ties. •Benefit: Increases the vibrancy of the area, making it more inviting and active throughout the day, especially in the evenings and weekends. <p>7. Multi-Modal Transportation Hubs</p> <ul style="list-style-type: none"> •Idea: Enhance connectivity by establishing a multi-modal transportation hub near Lujiazui Century Financial Plaza, integrating bike-sharing, public transit, and electric car sharing stations. This would provide alternatives to private car use, reduce congestion, and make the site more accessible. •Benefit: Improves transportation efficiency, reduces traffic congestion, and makes it easier for residents and workers to access the area without relying on cars. <p>8. Community Engagement and Cultural Programming</p> <ul style="list-style-type: none"> •Idea: Incorporate cultural spaces such as art galleries, performance venues, or event spaces within or near the site. These can be used for local art exhibitions, performances, or community events, allowing the building to serve as a hub for cultural expression. •Benefit: Promotes community engagement and helps reduce social isolation in the area, while also creating a cultural space for both residents and workers.

9. Rooftop Gardens and Urban Farming

•Idea: Use the rooftops of the high-rise towers for urban farming, community gardens, or even greenhouses. Residents and local workers can rent or share plots for growing vegetables, herbs, or flowers, which also helps improve food sustainability.

•Benefit: Adds green space to an area that lacks natural elements, improves air quality, and offers local food production in a dense urban setting.

10. Smart Technology and Sustainable Infrastructure

•Idea: Implement smart building technologies such as solar panels, rainwater harvesting, energy-efficient lighting, and automated waste management systems. These systems will help make Lujiazui Century Financial Plaza more environmentally sustainable and contribute to the city's broader green goals.

•Benefit: Improves the building's energy efficiency, reduces operational costs, and aligns with Shanghai's commitment to sustainability.

Summary:

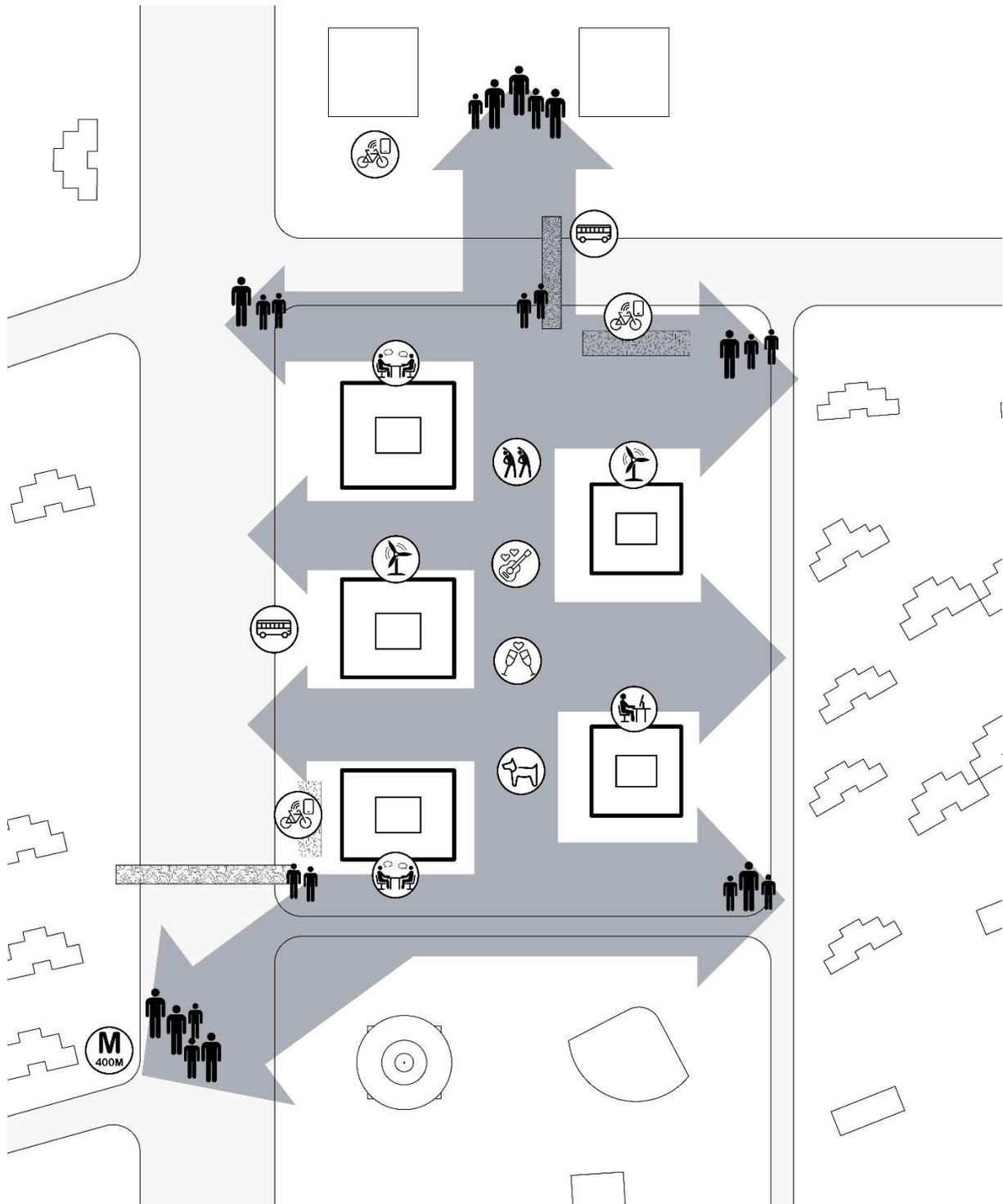
These urban design ideas aim to improve the integration of Lujiazui Century Financial Plaza with the surrounding plots and address urban issues such as vacancy, lack of green space, traffic congestion, and social isolation. By creating a mixed-use environment that blends residential, office, and community spaces, the project can foster a more inclusive, sustainable, and vibrant urban neighborhood.

Would you like further details on any of these solutions, or do you need additional help refining your design concepts?

ChatGPT's urban design strategies, while relatively conventional, demonstrate professionalism and practicality. Given the limited input conditions, the AI provided comprehensive solutions that address various urban design challenges.

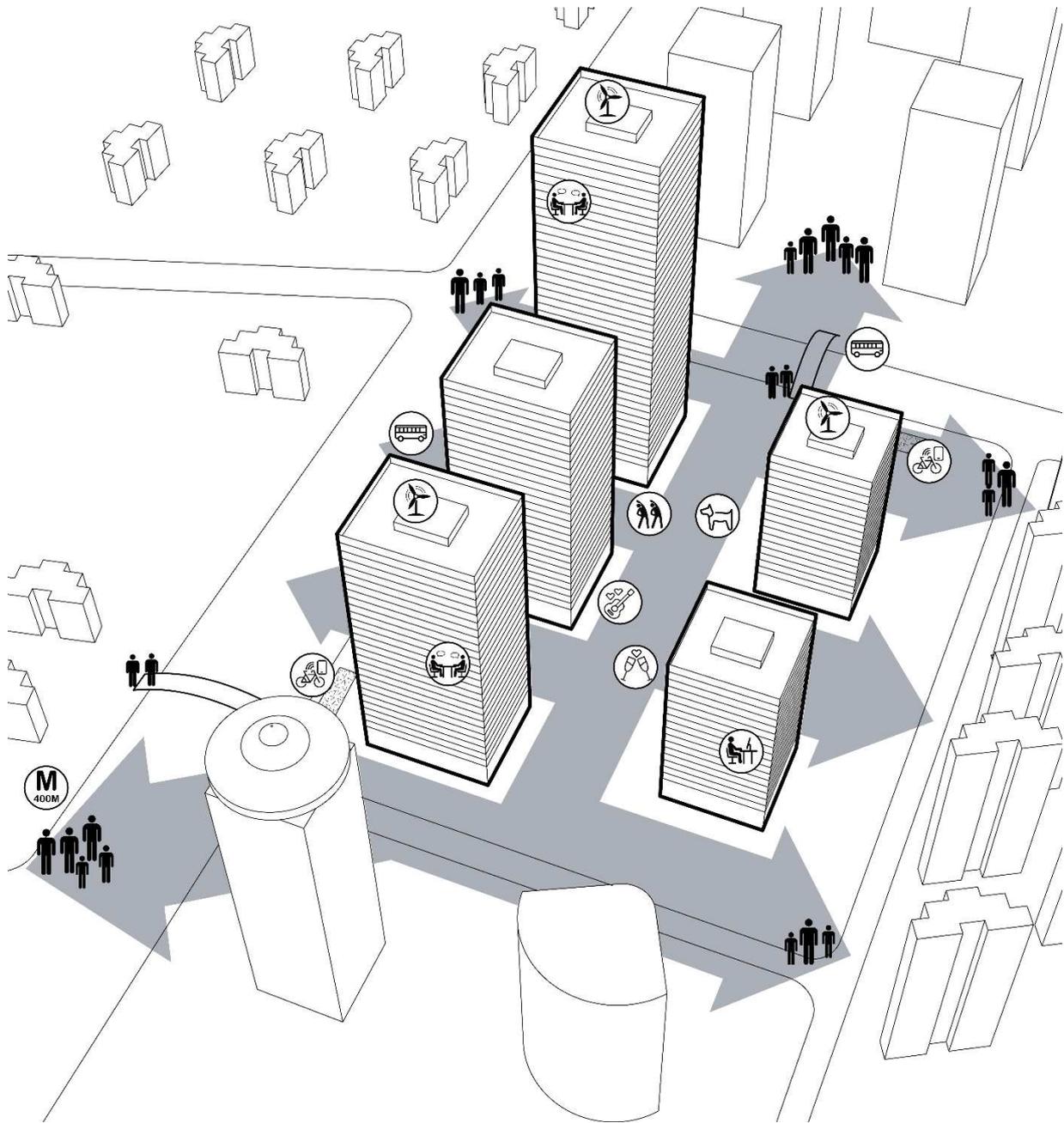
Most strategies are well-suited to the site and **align with competition requirements**. For instance, to tackle vacant office buildings, ChatGPT proposed adaptive reuse strategies. It also suggested ways to activate surrounding areas, such as improving transportation and introducing mixed-use functions to integrate nearby urban spaces. While the feasibility of some strategies (points 9 and 10) requires further exploration, ChatGPT also introduced sustainability-focused solutions that align with competition goals. Overall, the AI provided a comprehensive and inspiring urban design strategy.

However, due to current limitations in AI-generated image precision and control, it is necessary to combine traditional 3D modeling tools to refine and develop ChatGPT's strategies further. As shown in the **figure 30**, ChatGPT's strategies are practical. With further designer adjustments and implementation, it is possible to efficiently develop an initial urban design proposal.



Connect the urban space from the Southwest corner, the nearest Metro station, to the North, another office plot with public plaza to create an urban axis, and links all the nearby plots.

(a)



By doing this, connect all the public space into an united urban system. Adding pedestrian bridges, bike parking, bus station to enhance the traffic condition.

(b)

Fig. 30. Masterplan (a) and urban axonometric view (b) of the selected site, which combined the design output form ChatGPT. *Source: Done by author.*

4.5 Assessment and Challenges

Language-based AI, such as ChatGPT, has significantly improved efficiency in the design workflow. It supports designers in the early stages of design competitions by helping with document analysis, competition research, urban site selection, brainstorming, and proposing urban design strategies. This reduces repetitive tasks, allowing designers to focus on refining their concepts.

The DALL-E image generation tool, integrated with ChatGPT, is also valuable for producing conceptual visuals. It effectively conveys atmosphere and design vision. Additionally, as ChatGPT's image understanding capabilities evolve, combining text and image processing may provide even greater support for designers in the future.

While ChatGPT currently generates fewer highly innovative design strategies, its analyses are comprehensive and feasible, making it a reliable tool to support the design process and complement human creativity.

Future Design Approaches

Design methods are likely to become more diverse and text-based. Strategies based on **user needs, experiences, emotions, and atmospheres**—elements expressed through words—may serve as new starting points for design. This shift could reduce reliance on a designer's personal knowledge and experience, expanding opportunities for creative exploration.

Challenges and Limitations of AI in Design

Despite its potential, ChatGPT has several limitations that impact its application in urban design and architecture:

- **Incomplete Data:** ChatGPT's knowledge is limited by its training data, leading to gaps in information and an inability to access the latest or specialized datasets.
- **Unclear Focus Strategies:** Some proposed strategies, while logical, are impractical or difficult to implement, resulting in empty statements lacking actionable depth. Even with further feedback, refinement is not always effective.
- **"Black Box" Nature:** AI's decision-making process is opaque, meaning that small changes in question phrasing or timing can lead to different answers without clear reasoning.
- **Demand for Professional Prompts:** Effective AI interaction requires clear, precise, and professional language, placing an additional burden on users to frame questions correctly for meaningful responses.

Despite these challenges, AI's role in design is growing, and with further advancements, it has the potential to become an even more powerful tool for architects and urban designers.

Chapter 05: Stable Diffusion AI Applied on Architectural Design- from Sketch to Concept Decision

5.1 Stable Diffusion Introduction

5.1.1 What is and Why Stable Diffusion

Stable Diffusion is an AI model for image generation, editing, and creative applications. Released in 2022, it is based on diffusion models that learn to transform random noise into detailed images.

For architects and urban designers, Stable Diffusion offers a fast way to explore, conceptualize, and present ideas, especially using simple inputs like sketches or 3D model screenshots.

Among the top text-to-image AI tools—DALL·E, MidJourney, and Stable Diffusion—Stable Diffusion stands out for its high level of control. Unlike other models, it is more adaptable for architectural workflows and has already been adopted by international firms like Foster + Partners and Heatherwick Studio.

Stable Diffusion is a desktop-based tool with relatively low hardware requirements. All results in this section were generated using an RTX 3060 GPU with 6GB of VRAM. A lightweight web-based version is also available, enabling designers to work quickly and present designs to clients with ease.

While mainstream AI image-generation tools like MidJourney and DALL·E produce high-quality visuals, they lack precise control due to the unpredictable nature of text-to-image generation. This makes them less suitable for architectural design, where modifications and refinements are crucial. However, with the integration of ControlNet, Stable Diffusion has significantly improved in controllability, allowing for better integration with traditional design tools and localized modifications of generated results. These capabilities make it more practical for use throughout the entire design cycle.

By integrating Stable Diffusion into the design workflow, we can gain a broader understanding of how AI can be applied across various stages of the conceptual design process in architecture.

5.1.2 From Prompt to Picture Workflow

Stable Diffusion generates images from text prompts through a multi-step process. First, the text prompt is processed by a CLIP encoder, which translates it into a numerical representation

(token embedding) that captures its semantic meaning. This embedding guides the core image generation process, where a U-Net neural network and a scheduler iteratively refine random noise into a structured image tensor, following a diffusion process. This intermediate tensor represents the foundational structure of the image, in a latent form.

The structured tensor is then passed to an image decoder, which converts it into a high-resolution, visible image. By combining text understanding, iterative denoising, and decoding, Stable Diffusion produces images that align with the user's textual input. This system can be enhanced with tools like ControlNet, allowing for greater control and adaptability, making it particularly useful in applications, like architectural design.

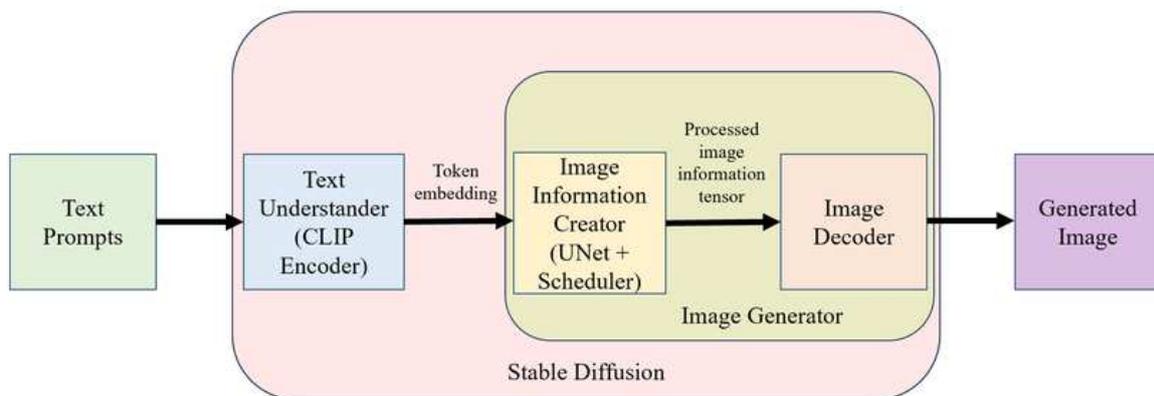


Fig. 31. The workflow from text to image in Stable Diffusion. *Source: Wu et al. 2024*
https://www.researchgate.net/publication/380916485_Syn2Real_Detection_in_the_Sky_Generation_and_Adaptation_of_Synthetic_Aerial_Ship_Images

5.2 Understanding the Integration of ControlNet with Stable Diffusion AI

5.2.1 “ControlNet” inside Stable Diffusion

Stable Diffusion was chosen for its powerful control capabilities, largely enabled by ControlNet. Released in **2023** by researchers at Stanford University (Zhang, Rao, and Agrawala 2023), ControlNet enhances image generation by providing greater precision and control over the output. This makes it particularly suitable for design-related tasks where composition and details must be carefully directed.

ControlNet extends Stable Diffusion by introducing conditional inputs, allowing users to guide the image generation process. It starts with an input image, such as a sketch or photograph, and extracts key visual features to provide structural guidance. This ensures that the generated image follows the intended composition while maintaining alignment with the provided input.

The system combines this structural guidance with text prompts, balancing creative freedom and precision. Stable Diffusion refines the output iteratively, ensuring that the generated image adheres to both the structural input and textual descriptions.

The result is a high-quality image that merges artistic creativity with **controlled accuracy**. ControlNet supports various input conditions, such as sketches or depth maps, giving users more control over the final output. This makes it particularly useful in design and architecture, where both creativity and adherence to specific visual requirements are essential.

In design workflows, ControlNet enhances Stable Diffusion’s applicability by supporting **frequent adjustments**, including sketch refinements, model modifications, localized edits, and the integration of reference images. AI-generated visuals can also be iteratively reused and modified, making reconstruction and refinements a key function. This iterative capability is crucial for meeting the dynamic and evolving needs of design tasks, reinforcing ControlNet’s importance in architectural and creative applications.

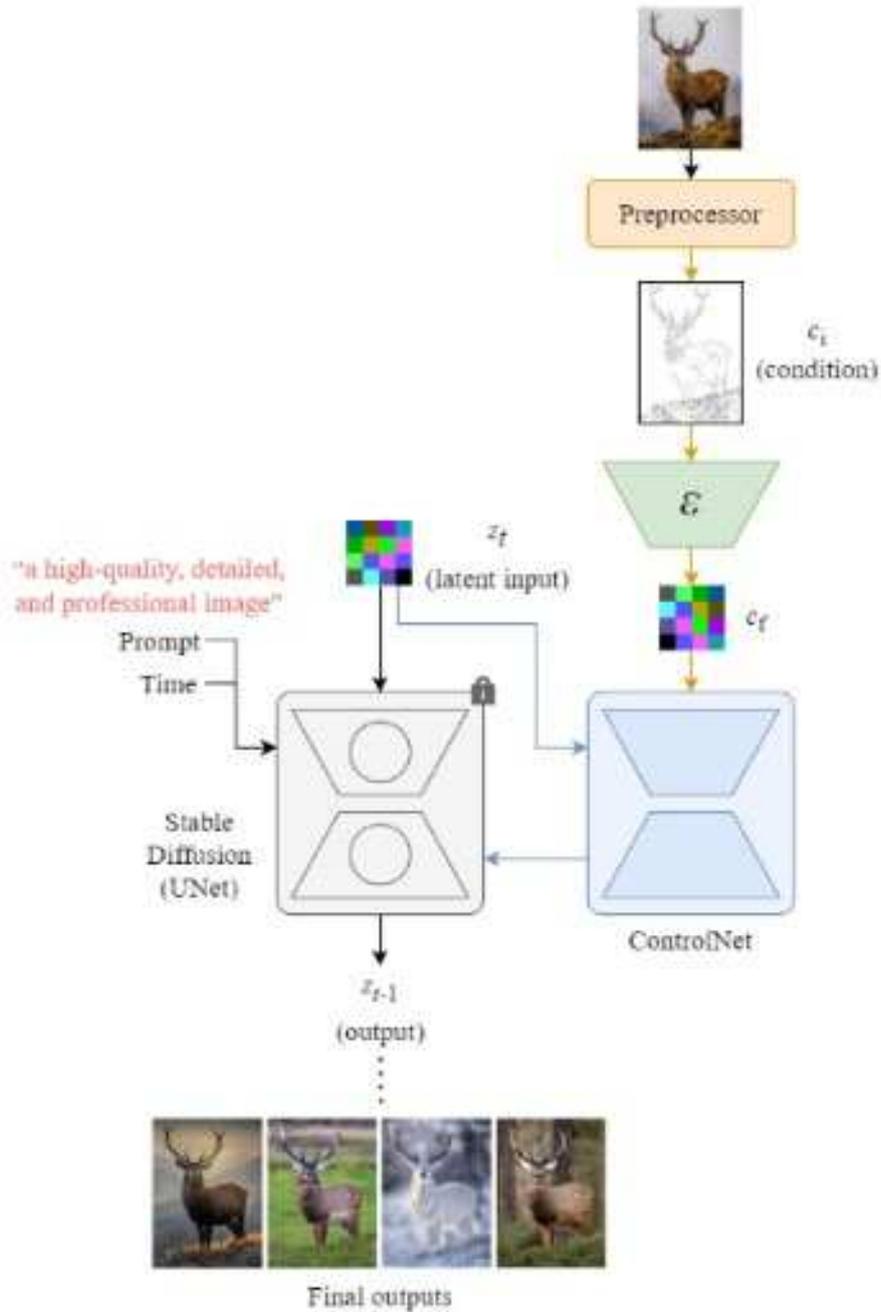


Fig. 32. The flow of one denoising step on ControlNet. *Source: Steins 2023.*
<https://medium.com/@steinsfu/stable-diffusion-controlnet-clearly-explained-f86092b62c89>

5.2.2 Sketch interface with Stable Diffusion

To better harness AI, we must first understand its capabilities. To explore how sketches interact with AI, we used a base image and processed it through ControlNet. This step generated several sketch variations commonly used in architectural design, differing in detail richness, line thickness, light and shadow relationships, and random line distribution (Step 2).

These variations illustrate how a single image can be interpreted at different levels of abstraction and detail.

Next, we input the same text prompt into Stable Diffusion, keeping all other parameters unchanged. Common settings such as sampling methods, VAE, CFG (set at 7), and pre-trained models were used to ensure consistency. This process generated five different outputs, revealing that Stable Diffusion can effectively interpret sketches and transform them into detailed concept images. This ability is further enhanced by large models optimized for architectural design within Stable Diffusion.

In the first three tests, even sketches with imperfect elements (e.g., curved lines deviating from reality) were successfully transformed into detailed concept images with accurate depth and scale, making them suitable for early-stage concept design. However, the last two methods, which lacked sufficient line detail, resulted in greater deviations (e.g., Option 4) and less accurate outputs (e.g., Option 5).

Despite these limitations, Stable Diffusion demonstrates a strong ability to interpret design intent, even when working with flawed sketches. These results suggest that AI-generated outputs can serve as valuable inspiration in the earliest stages of the design process.

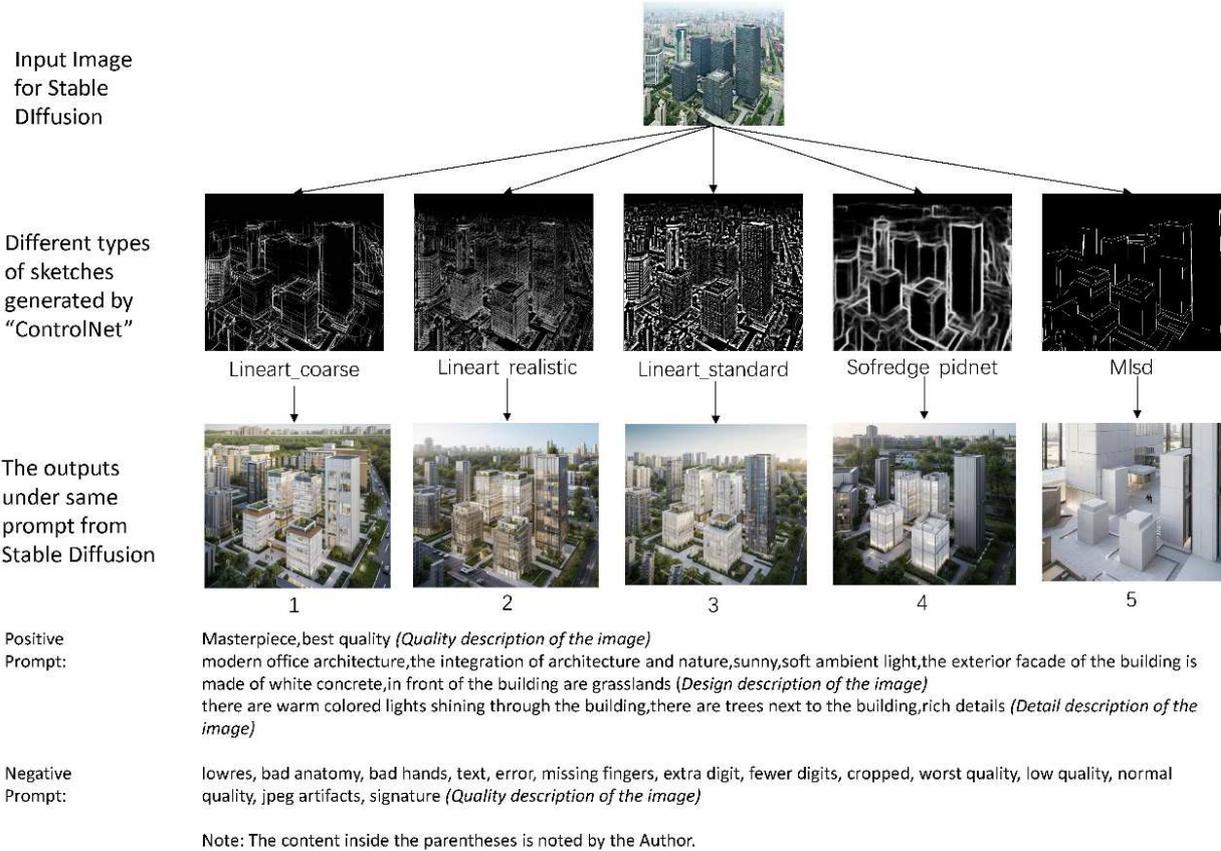


Fig. 33. The different ControlNet control modes testing. *Source: Done by author on Stable diffusion.*

In conclusion, during the early stages of design, when using sketches combined with textual prompts to generate images with Stable Diffusion, the tool demonstrates remarkable flexibility. Even if the sketches are imperfect or include unintended lines, as long as they meet a certain depth requirement, and are paired with appropriate textual prompts, Stable Diffusion can effectively interpret human intent. It can produce images that largely align with design requirements, making it a powerful tool for generating concept visuals, in the initial phases of architectural design.

5.3 Sketch-Driven Design with Stable Diffusion AI

5.3.1 “Lora” model

The LoRA (Low-Rank Adaptation) model is a method used in Stable Diffusion to enable efficient fine-tuning. Instead of retraining the entire model, which requires significant time and computing power, LoRA adjusts only a small set of parameters. These small modifications help the model learn new styles, adapt to specific tasks, or meet unique design needs, without altering its core structure.

This **lightweight** approach is particularly useful in architectural design, where quick customization is essential. With LoRA, Stable Diffusion can learn specific architectural styles or details, making generated images more accurate and relevant to a project. This enhances the design process, allowing designers to achieve customized results with minimal computational resources.

In Chapter Four, we explore the transformation of partially vacant high-rise office buildings into residential units. To foster a sense of community for young residents, we propose simple architectural modifications, such as adding connections between high-rise living areas to form community hubs. Additionally, greenery and sustainable facilities are integrated to enhance livability and environmental impact, aligning with a long-term design vision.

The LoRA model proves particularly valuable in this context. Using the same sketch as input but adjusting different LoRA models, designers can generate varied architectural styles while keeping text prompts unchanged. This flexibility allows for diverse stylistic exploration of the same concept. The diagram below demonstrates how applying different LoRA models with identical prompts produces a range of design ideas, offering rich inspiration for architectural exploration.

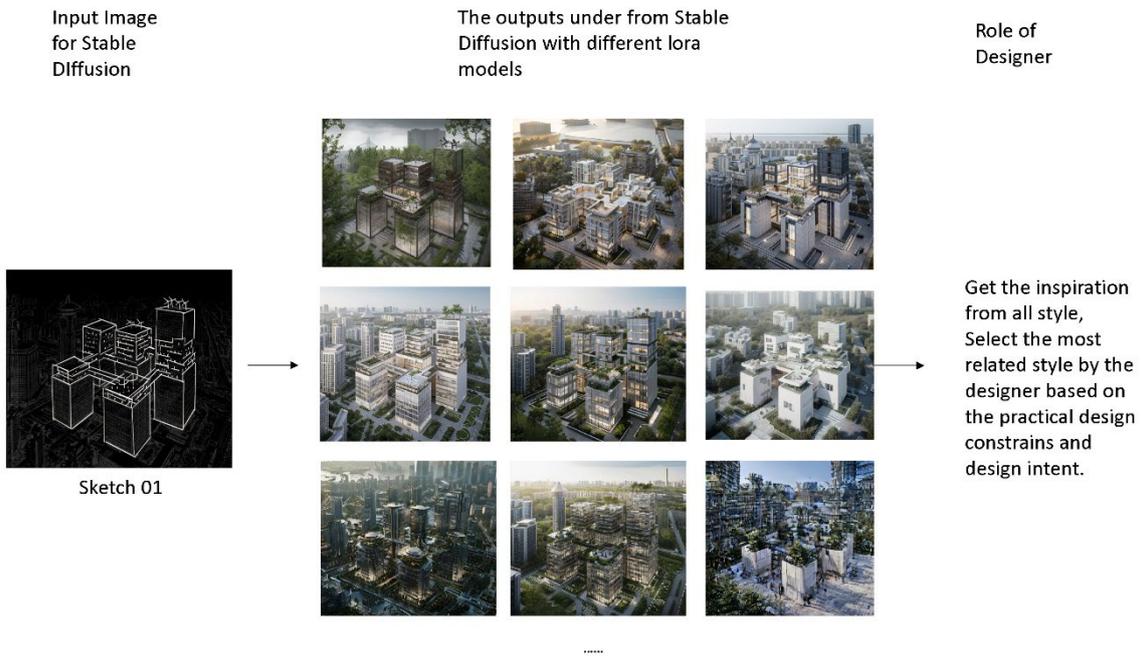


Fig. 34. The different lora models testing. *Source: Done by author on Stable diffusion*

We can also achieve new designs by simply modifying the text prompts while keeping all other elements unchanged, achieving effects similar to those obtained using the LoRA model. Importantly, both approaches belong to the same method category. By adjusting the textual input, the generated outputs can reflect diverse styles and ideas, offering flexibility in design exploration.

In essence, the LoRA model is integrated within the text prompts, meaning the model's adjustments are embedded into the descriptive inputs. This demonstrates the adaptability of combining LoRA with prompt engineering, allowing designers to experiment with different stylistic directions efficiently, while maintaining consistency in other design parameters.

5.3.2 Refine Design by Sketch

Using a new sketch with a similar depth as the previous one, we selected the options from earlier tests that were deemed more aligned with design requirements and practical feasibility. After refining the design in the sketch, another round of testing was conducted. This time, the updated sketch emphasized the distinction, between residential and office areas, addressing a limitation observed in the earlier designs.

By generating architectural designs based on the new sketch and nearly identical text prompts, Stable Diffusion demonstrated its ability to understand different facade design intentions. The results showed a clear differentiation between the styles of the residential and office areas,

aligning closely with the design objectives. The generated images provided accurate scales and atmospheres, allowing for a foundational understanding of the future design, and establishing a clear design direction.

However, due to limitations in the dataset used by the large model or the LoRA model, the generated designs from the same LoRA model tended to exhibit similar styles. As a result, this iteration provided limited new inspiration for the design concept. For instance, the facade designs in this round highlighted the need for designer input to refine, and propose better solutions, underscoring the importance of human feedback, in the creative process.

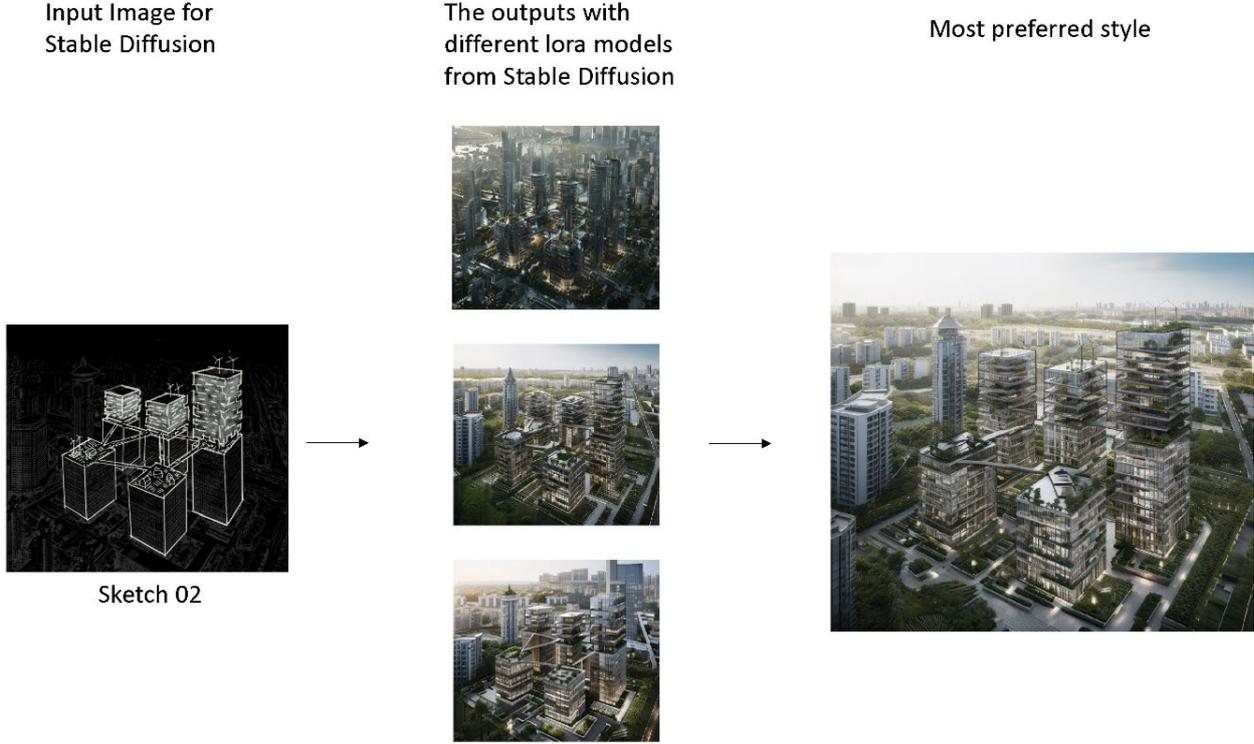


Fig. 35. Design varies from sketch to rendering. *Source: Done by author on Stable diffusion.*

5.4 Integrate into traditional 3D Design tools

5.4.1 3D Tools in Conceptual Design

Compared to hand sketching, 3D modeling software provides more precise control over designs. However, traditional 3D modeling tools require significant effort, from initial modeling to final output. The typical workflow includes creating 2D sketches, manipulating 3D forms, applying materials, adding environmental elements, and fine-tuning renderings in specialized software. Due to complex interfaces and numerous commands, these tools can be challenging to master.

Taking **Rhino** as an example—a widely used tool in design firms—learning its modeling logic requires time and hands-on experience in real projects. As a result, proficiency in 3D modeling has become a key skill that firms look for when hiring.

3D models serve two primary purposes in the early design phase:

1. **Sketch Models:** Used to quickly test and explore design concepts, allowing teams to compare multiple options. These models lack detail and are mainly for internal discussions rather than final presentations.
2. **Refined Models:** More detailed and continuously developed for final visual presentations, technical documentation, and as a reference for later design stages. These two phases are iterative, rather than following a strict linear process.

While 3D models are essential design tools, they are ultimately computer simulations. Interaction is limited to the screen, which can mislead designers' perceptions of real-world conditions. This is why renowned design firms still emphasize physical models in conceptual design.

Additionally, inexperienced designers often struggle with real-world scale in 3D modeling. They may become overly influenced by software display modes instead of focusing on accurate spatial representation. Current 3D tools remain far from replicating real-world environments.

Despite their precision, 3D models are not always the best medium for exploring broader design possibilities. Most traditional 3D software prioritizes engineering-focused interfaces, which do not fully capture real-world experiences. Rhino, for example, originates from industrial design and was not initially created for realistic architectural visualization. Currently, no 3D modeling software balances precision, usability, and real-world simulation specifically for architects.

The rise of language-based generative AI challenges whether conventional 3D modeling approaches are truly the best for architectural design. As discussed earlier, design intent, real-world experiences, and atmosphere can often be better conveyed through text, images, videos, or animations rather than static 3D models.

As of January 2025, **AI-powered text-to-3D tools** are still in their early development stages. No mature AI tools yet exist that can accurately and efficiently convert images or text into 3D models. However, with advancements in text-to-3D technology, this may soon become a reality.

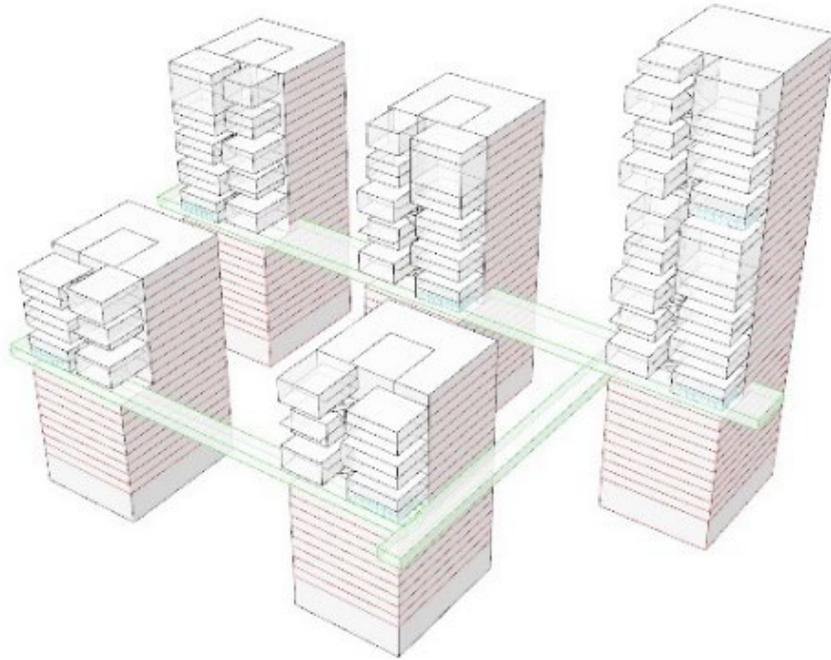
Given these factors, this study utilizes Rhino, the most widely used 3D modeling software in major international design firms, for the conceptual design phase. Additionally, Stable Diffusion's image-to-image capabilities were employed to generate design drafts for testing purposes, exploring AI's potential in the early design process.

5.4.2 Integrate AI with Traditional 3D Tools

Based on the design options discussed earlier and ChatGPT's suggested concepts, the following design volume was selected for testing:

- Retaining the overall form of five super high-rise towers
- Transforming the southern-facing sections into smaller residential units
- Connecting the towers at the base level of the residential units with aerial bridges

After modeling the volumes in Rhino (Figure 36 a), screenshots from Rhino were processed in Stable Diffusion, using the same prompts as in the previous section. The generated results are shown in Figure 36 b.



(a)



(b)

Fig. 36. The screenshot of 3D model sketch (a) to the rendering as a design direction (b). *Source: Done by author on Rhinoceros and Stable diffusion.*

3D software provides better and more **precise control** over volumes, such as tower positions, edge lengths, and floor heights, making it an indispensable tool in the design workflow. However, since the design is still in the "sketch model" stage, strict precision is not yet required, allowing for flexibility in adjusting volumes. This openness preserves the exploratory nature of 3D modeling while enabling quick conversion of 3D models into realistic images with the assistance of AI. By combining 3D tools with AI-generated images from Stable Diffusion, the conceptual design direction can already be effectively established.

Tools for converting text or **images into 3D models** are gradually emerging, enabling mutual transformation across text, images, videos, and 3D models. These tools could eventually replace traditional 3D modeling in the early conceptual design phase, offering better volume simulations and improved design visualization. Currently, 3D models serve primarily to provide precise control over form and space, a function that AI-generated models are increasingly capable of handling. While AI-generated content still faces technical challenges, ongoing developments suggest that traditional workflows for testing design concepts may soon be optimized by more advanced AI-driven approaches.

While **engineering precision** in 3D models remains irreplaceable in the later stages of design, AI-generated models can complement traditional tools. For instance, AI can explore design possibilities in different formats—text, video, or images—and generate 3D models as a foundation for refining conceptual designs. Designers can then manually adjust and precisely control these models to complete the final concept. Throughout this process, AI tools provide a more intuitive and realistic way to interact with design ideas.

In other words, AI should be integrated into the design process to create tools that align more closely with **real spatial experiences, atmospheric qualities, and user needs**, rather than keeping design methods solely dependent on engineering-oriented tools.

5.5 Assessment and Challenges

This chapter explores architectural design workflows using Stable Diffusion as an example. Compared to traditional workflows, it reduces reliance on traditional 3D design tools, which are more suited for engineering tasks. Designers increasingly use text inputs or sketches, combined with pre-trained AI models, to generate images and test designs more efficiently. These images help in visualizing design atmospheres and clarifying concept directions.

Through **sketch iterations**, AI tools like Stable Diffusion enable designers to create inspiring and atmospheric visuals. While traditional 3D tools remain essential for precise control, AI-generated images now play a key role in guiding subsequent design steps.

As image-generation tools advance, alongside the development of text-to-video and text-to-3D tools, the conceptual design phase will become significantly shorter. This will reduce repetitive tasks, such as manual adjustments in 3D engineering tools. New design tools will also introduce new approaches, allowing designers to create experiences through text, better express user needs, and describe design requirements more accurately.

Challenge

However, these AI tools come with risks. Since AI-generated designs are based on existing training data, they may lead to repetitive solutions or lack unique consideration for **local culture and societal context**. Additionally, similarities in outputs become apparent with repeated use, highlighting the limitations of AI training data.

Traditional methods, such as physical or digital 3D models, remain valuable despite being time-consuming. This suggests that over-reliance on AI could limit creativity rather than enhance it. A balanced approach that integrates AI with traditional design techniques is necessary to preserve innovation and originality.

Beyond design, AI raises concerns about unemployment, copyright, and ethics, which must be carefully considered as these tools continue to evolve.

Chapter 06: Outcome, Discussion, and Conclusion

6.1 Outcome: The AI assisted Design Process

At the start of a design mission, understanding the design brief is essential—from interpreting documentation to conceptualizing the vision. AI can efficiently assist researchers and designers in this stage. ChatGPT, for example, integrates seamlessly into the process by summarizing complex documents, helping designers comprehend key details, and facilitating deeper understanding.

When combined with DALL·E, AI enables a text-to-image workflow, allowing designers to visualize ideas early and gain a clearer sense of the design vision. ChatGPT also acts as a brainstorming assistant, generating creative suggestions and aiding in design research.

As the process advances to the conceptual design stage, tools like Stable Diffusion, ControlNet, and LoRA models become instrumental. These AI-driven tools help designers create concept visuals efficiently by refined sketches. By integrating them with traditional 3D tools, such as Rhino, designers can rapidly explore multiple design options, balancing AI-generated ideas with manual adjustments to align with project requirements.

Beyond visualization, AI tools assist in integrating other design information, such as user behavior and other design parameters to ensure solutions are not just visually appealing, but also contextually relevant and sustainable. By leveraging AI, designers can achieve comprehensive results in significantly less time.

The AI Assisted Conceptual Design Workflow

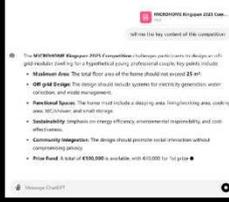
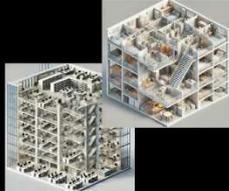
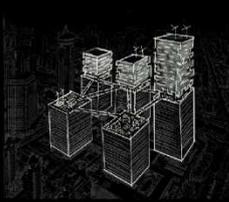
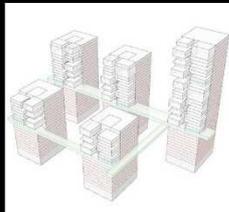
	Tools	Steps	Process results
AI tools	ChatGPT	Mission Understanding + Research	 
	ChatGPT + DALL·E	Inspirations + Idea Testing	 
AI tools + Traditional Tools	Sketch + Stable Diffusion	inspiration + Design refine	 
	Rhino 3D + Stable Diffusion	Massing + Draft Render	 

Table 8. The “AI assisted workflow” from research to the decision of design concept on the conceptual design process of a competition. *Source: Done by author.*

6.2 Open Discussions

6.2.1 Limitations and Solutions

Workflow Limitations

AI is not completely reliable, and human checking is still necessary. For example, when understanding text, AI is fast but might miss some details. In real projects, design information needs to be handled carefully. Mistakes or missing details in the early design phase can cause big problems later.

Relying too much on AI can make us lose the traditional way of creative thinking about design, especially during brainstorming. AI might not truly understand human feelings, culture, or real-life experiences. Even though AI's answers seem good and professional, they are based on limited data and might not fully understand what designers need.

This thesis is not suggesting that we should stop using traditional design methods. Even though they take more time, deep thinking in that process is important for creativity and imagination better than AI. For example, AI can create amazing images, but these are based on existing data. They don't show real imagination or new ideas.

AI-generated results still have some problems. This is mainly because of the data used to train AI and the fact that AI technology is still improving. Sometimes, using the same data leads to similar results. Also, AI is still trying to balance creating good designs and giving designers control over the process.

Ethical and legal issues are also important to think about. AI uses a lot of data from the internet, which might include copyrighted material. In addition, as AI tools become more popular, there is a risk that many designs will look the same, even in different locations.

Proposed Solutions

The impact of AI on the design industry might be as huge as the Industrial Revolution. Currently, the best approach is to combine AI with traditional methods. This way, we can keep the quality of design while working faster. Just like how computers started replacing hand-drawing, but it didn't stop us from using tools like sketches or physical models, AI should be part of the design process. It can help us work faster and be more creative.

Designers need to think critically about using AI. They should understand how it works and not rely on it too much while limiting their creativity. By learning about AI and trying it out, designers can use it better and make smarter decisions about when to use its power.

It's also important for designers to start learning about AI now. Just like how designers learned to use CAD in the past, AI is the next big step. Designers shouldn't be afraid of it. AI already

has many useful features, and learning about it can be fun meanwhile. In addition, using AI well requires good communication skills, like writing clear instructions, which isn't time consuming to learn but can make a big difference.

Finally, designers and developers need to be aware of copyright, ethical, and legal issues when using AI.

6.2.2 Perspectives

Future trend of AI in Design Industry

AI tools can save a lot of time and money for design companies. As the technology improves, more companies will start using AI. AI can handle repetitive tasks quickly, making designers more efficient. It also helps designers do more, like creating renders, animations, or construction drawings easily. Companies that use AI earlier will have an advantage.

However, as many specialized design fields are gradually replaced by AI, especially in industries that require less creative thinking, the overall demand for designers may decrease. This phenomenon is not unique to the design industry but is similar to the impact of the Industrial Revolution on various sectors.

Current AI tools are still in the category of "Narrow AI." They can only perform specific tasks and have not yet achieved true "understanding" or the ability to be creative or integrate knowledge across fields. This limitation may improve with the development of "Artificial General Intelligence" (AGI). AGI is defined as an intelligent system that can perform multiple tasks, achieve various goals, and operate in different environments and situations (Goertzel 2014). Generally, AGI can perform a wide range of tasks, understand complex concepts, and learn and reason on its own, much like humans. If AGI is achieved, AI may truly possess creativity.

However, the timeline for AGI remains highly uncertain. Many well-known entrepreneurs, such as Sam Altman, Jensen Huang, and Elon Musk, predict that AGI will arrive within the next few years. But some scholars believe it is still unknown whether AGI can even be achieved. With the rapid development of large language models in recent years, Geoffrey Hinton, a pioneer in AI, stated in 2023: "AGI may be achieved in less than 20 years and could bring changes as significant as the Industrial Revolution or the advent of electricity" (Jacobson et al. 2023).

No matter how fast AI develops or what the outcome is, human intelligence has not significantly improved, while machines and technology continue to advance. Therefore, AI will gradually replace some of the work done by designers, and this has already begun.

The Concern about AI replace the human designer

At this stage, AI cannot replace human designers but rather extends human creativity, fear is unnecessary. Technological revolutions are neither new, nor final. While the new generation of AI technologies is beginning to exhibit creative capabilities, which once unique to human intelligence, AI outputs still rely on training with existing data, lacking independent thinking, and far from surpassing the human imagination.

In the near future, AI might do better than humans in areas like making standard, functional, sustainable, and practical designs. But it's still unclear if AI can surpass humans in creativity, especially in expressing emotions, understanding culture, or communicating with clients.

The more unique and complex human skills are, the harder it will be for AI to replace them. For example, unique art creation, emotional expression, multi-dimensions sense, and deep communication are very human skills that AI can't easily copy. From the beginning of human history, invention and creation have never decrease, and it will continue into the future.

The necessity of AI on Design Education

Using AI as a powerful tool in design education will undoubtedly bring great value. Whether AI will revolutionize design practices is still debatable, but as a cutting-edge tool and part of workflows, AI has already reached a certain level of maturity. It is practical and will gradually become an essential skill for designers.

Like education in other fast-growing industries, there are delays in applying AI to design education. Even if educational institutions recognize the importance of AI tools, hiring and training teachers with relevant skills, and helping students learn these skills through education, takes a lot of time and resources. Meanwhile, technology keeps advancing rapidly.

However, since AI is still in its early stages, planning its integration into education now is crucial. This will help future design education better integrate new technologies and methods.

Since the technology changes so quickly, relying only on schools for education is not enough. In the future, online education for new technologies should be more organized and systematic, serving as a supplement to traditional design education. For areas where schools lack the resource, students can start learning on their own online. This has already become a common way for students to learn many software skills.

While online content is timely and rich, with many high-quality resources available, it is often inconsistent and lacks structure. Investing more in this area would bring significant benefits. It wouldn't cost much but could have a wide-reaching impact.

6.3 Final Conclusion

This thesis explores the integration of current Artificial Intelligence (AI) technologies, such as ChatGPT, DALL·E, and Stable Diffusion, into the conceptual design stages of architecture and urban design. It focuses on how these tools enhance efficiency and creativity while complementing traditional design processes.

The outcome reveals that AI tools significantly enhance efficiency and solidly support creativity during the conceptual design phase. However, traditional design tools remain indispensable, and combining the two can promote innovative design models that better align with user needs and experiences. Despite these benefits, challenges such as data limitations, inaccuracies, and ethical concerns highlight the need for critical thinking when using AI.

Chapter 1 outlines the history of AI and its applications in design. Chapter 2 provides a literature review and case studies, analyzing AI's current role in urban planning, urban design, and architectural design. Chapter 3 breaks down the conceptual design phase and introduces the "8th MICROHOME Design Competition" as a case study to support the practical research.

Chapters 4 and 5 form the core of the research. Chapter 4 focuses on ChatGPT's application in urban design research and strategy development. It demonstrates how ChatGPT assists the designer in understanding competition tasks, analyzing user needs, brainstorming ideas, and proposing design strategies, while integrating DALL·E for visualization. This chapter highlights ChatGPT's ability to improve efficiency and stimulate creativity but also notes its limitations, such as data biases and the need for manual verification. It emphasizes the importance of professional interaction skills and critical thinking for designers.

Chapter 5 focuses on the specific application of Stable Diffusion, in the conceptual phase of architectural design. It examines its image generation and control mechanisms, integration with traditional design sketches to explore and advance ideas, and combination with 3D modeling tools to refine design directions. The chapter analyzes Stable Diffusion's potential to enhance efficiency, creativity, and improve the traditional workflow, while addressing its challenges in the same time.

The thesis also raises open questions about the challenges posed by AI tools, such as over-reliance potentially leading to a lack of social and humanistic considerations in design, the limitations of training data sources causing design homogenization, inaccuracies in data misleading design decisions, and ethical and legal concerns, that require greater attention.

Technological advancements often transform job demands and traditional workflows. The AutoCAD in the late 20th century is a prime example, liberated designers from the era of laboriously working at large drafting tables, with drawing boards, pencils, erasers, and T-squares. Similarly, AI tools offer new possibilities but do not eliminate the need for traditional methods.

However, just as horses were not entirely replaced by cars as a means of transportation, and handmade models design method did not disappear with the rise of 3D modeling software, technological innovation provides designers with more choices.

Whether to actively learn and apply these new tools, is a matter of individual choice, but the tide of technology development would force quicker decisions. Embracing AI critically can unlock new possibilities, ensuring the design profession evolves to meet future challenges.

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