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A Review: Exploring AI's Role in Architecture: Redefining New Design Interactions

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Abstract

The use of artificial intelligence in architecture has had a significant impact on the profession, sparking debate about its potential to fully automate architectural work. However, there is limited research on the influence of AI across all phases of the architectural design process. This article aims to analyze the extent of AI's impact on architecture and to identify potential future benefits and challenges. The phases of architectural work discussed include pre-design, schematic design, design development, construction documentation, negotiation, and construction observation. Through a systematic literature review, this study highlights the transformative impact of AI across all stages of architectural design, emphasizing emerging concepts of design interaction and their implications for the profession. The findings suggest that while AI cannot fully replace architects, it indicates a shift in their role by enhancing collaboration and work flexibility. Nonetheless, the study emphasizes the importance of strengthening architects' technological competence in using AI tools to ensure their continued relevance in the future.

INTRODUCTION

Digital technology has been used in almost all aspects of human life. Industry 4.0, the "era of digitalization," has significantly changed how humans work, communicate, and search for information (Galanti et al., 2023). Various technological innovations have positively impacted human work, such as artificial intelligence, robotics, automated vehicles, 3D printing, nanotechnology, and so on (M. H. Lee et al., 2018). Even so, predictions that machines or technology will replace the role of humans in work continue to emerge. Massive technological developments in the future are expected to replace most jobs controlled or done by humans where routine jobs with low skills will be more vulnerable to being replaced by technology (Odeibat, 2021). Artificial intelligence (AI) is a digital technology product that has emerged massively in recent times. The presence of AI has changed the old paradigm regarding phenomena in the scope of work. AI is predicted to replace human jobs and cause unemployment, unrest, and social inequality among society groups in the future. For example, an auto-pilot taxi that designed unmanned driving activities on the highway or a 3D printer robot (Construction 3D Printing). These innovations show that the activity of driving on the road or technical work in construction can now be replaced by machines or technology.

AI also has made significant strides in the field of architecture, offering a plethora of potential benefits. Many architectural professionals have already begun integrating various AI-generated products into their design process. These include creating 2D and 3D image visualization designs, animations, or virtual reality experiences. For example, AI can analyze large datasets of building materials and their properties to suggest the most sustainable and cost-effective options for a project. AI is also poised to automate critical tasks in the architectural production stage, such as creating building drawings, designing electrical and mechanical diagrams, and generating project documentation in a more time-efficient manner. This underscores the role of AI in architecture as a valuable 'design assistant ', accelerating the design exploration phase and offering architects a wealth of creative and innovative data-based options. The use of AI in architecture opens new possibilities for design, allowing architects to explore more complex and innovative designs that were previously not feasible.

However, the issue of the sophistication of AI technology still requires careful study. The increasing development of AI in architecture has not been met with a corresponding increase in attention from architects, both as practitioners and academics (Lukovich, 2023). These limitations can hinder the interaction between architects or humans and technology (Gogoi, 2023). The unpreparedness of architects to enhance their competence in mastering technology can have a detrimental impact on the architectural profession in the future. This situation has the potential to undermine the crucial role of architects in overseeing design work. Several previous studies explicitly suggest several important actions, such as exploring how architects can adapt to changes in AI technology (Picon, 2020), exploring the potential for applying AI in architectural design (Hassab et al., 2023), examining the role of AI in each stage of architectural design more specifically starting from the conception process to construction (Bölek et al., 2023; M.Matter and G.Gado, 2024; Mrosla and Both, 2019). The field of architecture must enhance its comprehension of AI and technological advancements to equip architects with the necessary readiness to navigate forthcoming changes (Trabucco, 2021). The key challenge lies in striking a balance between AI technology and human expertise in the design process to achieve optimal outcomes (Vasiliu, 2024). It is imperative that we take proactive measures to develop adaptation strategies and pursue additional research to ensure the continued relevance and resilience of our profession in light of these technological advancements.

Therefore, this article presents a systematic literature review that aims to help architects determine their perspective towards AI developments in their work. It provides an expanded perspective on the impact of digital technology developments in every stage of architectural work and offers predictions on the potential for complete automation of architectural work in the future. This research aims to answer the following questions:

1) How is AI changing the way architecture and technology interact in design?
2) Can AI completely replace the role of architecture?

LITERATURE REVIEW

The topic of Artificial Intelligence in architectural work has shown significant growth in the last ten years. Previous research has discussed the impact of shifts in the architectural industry's working mechanisms that AI intelligent machines can adopt. The use of AI in the design process has impacted reshaping the relationship between humans and machines in the architectural design process (Picon, 2020). AI has formed a new paradigm in architectural work, namely a change in thinking in the planning or design process, where AI can play a significant role in finding solutions and alternative solutions to design problems but also provides consequences that need to be considered by architects (Lukovich, 2023).

In particular, AI has also helped produce more efficient and innovative building designs, pushing the architectural profession to explore new avenues during the design process. The primary approach of AI in architecture is to increase design efficiency, such as creating an automatic modeling process (intelligent simulation) that replaces conventional modeling processes and facilitating the architectural design process to improve work practices (Nabizadeh Rafsanjani & Nabizadeh, 2023). AI has enabled architects to analyze and optimize complex design problems that were previously difficult to solve and offer new ways of innovation and creativity in architectural practice (Bölek et al., 2023). The application of AI-based approaches, such as AI image generative in image visualization production, is also widely used. This condition allows AI to produce image visualizations quickly and representatively so that problems in time consumption are no longer an obstacle in the design process (Enjellina et al., 2023). As an illustration, the process of creating image visualizations that have previously been carried out by architects, starting with creating 3D models, rendering, and editing, can now be done by AI quickly by just writing simple text (prompts). Apart from that, the use of AI has also been widely used in the architectural conceptual design phase, namely helping architects in solving problems of finding complicated and complex design forms such as exploring more innovative and creative design forms to optimize architectural design forms (Castro Pena et al., 2021).

AI can now carry out architectural forms that were previously complicated for architects to explore through evolutionary computing techniques. AI in the architectural design process can also improve design efficiency, accuracy, and quality, enabling architects and designers to explore various options quickly (Hassab et al., 2023). AI improves the architectural design process stages by offering patterns, decision-making processes, data predictions, and presenting event information clearly (M.Matter & G.Gado, 2024).

Previous studies have provided strong evidence that the advancement of AI technology has significantly influenced architectural work in terms of effectiveness, efficiency, innovation, and overall quality. However, there is still a need for research to explain the specific impacts of AI on each architect's workflow. Mapping research gaps has revealed that further studies on the implementation of AI in architecture are necessary to deepen understanding and raise awareness among architects. Therefore, this research aims to address these gaps by detailing the specific use of AI at each stage of architectural work and by providing predictions on the future impact of AI on architectural practices.

METHODS

This research uses the Systematic Literature Review (SLR) method. SLR is a research method that combines the results of several previous research reports to formulate research questions, determine inclusion and exclusion criteria, conduct a comprehensive search, and involve two independent assessors to evaluate the research results (Owens, 2021). The SLR in this research follows a sequence by (Snyder, 2019) such as (1) designing the review, (2) conducting the review, (3) analyzing, and (4) writing the review (Figure. 1).

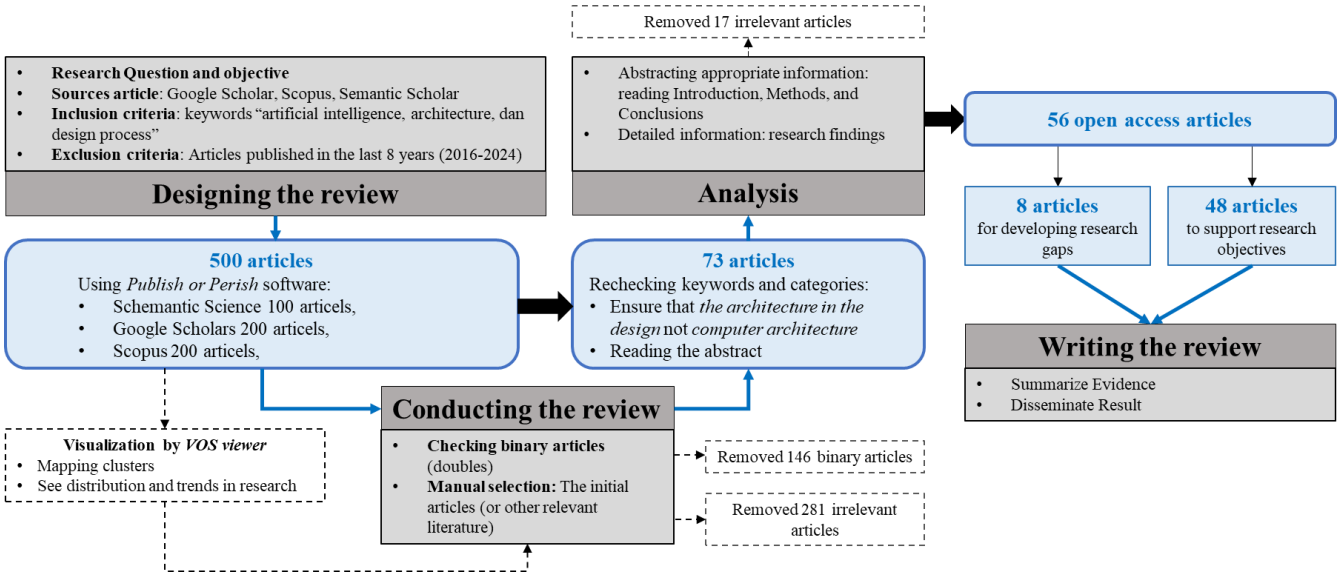


Fig. 1. Systematic Literature Review (SLR) Method Proces

Designing the Review of Literature

Designing the review begins with creating research questions and objectives to direct the specific literature search. Literature was obtained from reputable scientific journals and conference proceedings. The article search used keyword inclusion criteria, namely "*artificial intelligence, architecture,* and *design process*" and was limited to open access articles published in the last 8 years (2016-2024). The search used the "Publish or Parish" platform and succeeded in collecting 500 articles consisting of: (1) Schemantic Science 100 articles, (2) Google Scholars 200 articles, and (3) Scopus 200 articles. All articles are then input into VOSviewer to create data visualization (Figure 2). The visualization results show that research related to AI is generally divided into 4 clusters, namely, (1) AI mechanism, (2) AI as design process, (3) AI prediction; and (4) AI applications.

Specifically, the AI as design process cluster (green group) shows issues regarding the relationship of AI in the architectural design process spread across twelve domains which are sorted based on relevance and level of connection, namely; (1) building, (2) methodology, (3) construction, (4) architect, (5) design process, (6) integration, (7) exploration, (8) industry, (9) designer, (10) education, (11) impact, and (12) design method (Figure 3).

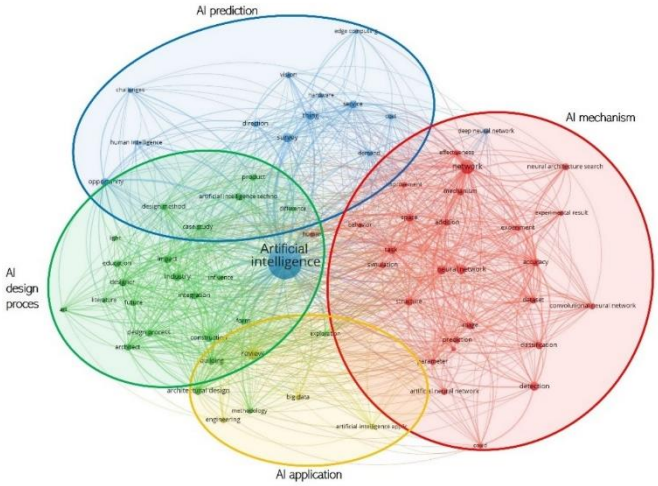


Fig. 2. The VOSviewer Visualization Shows A Grouping of 4 Main Clusters in AI Research

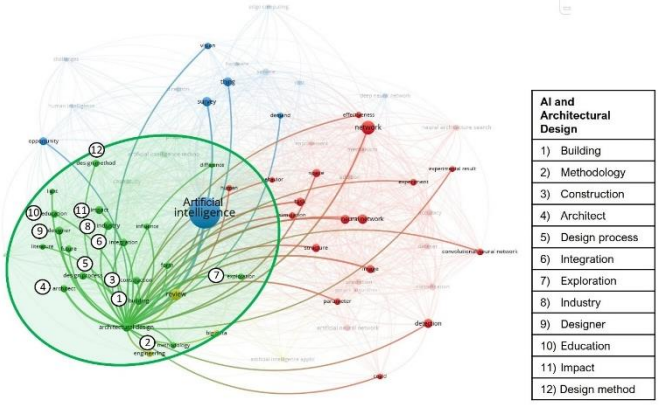
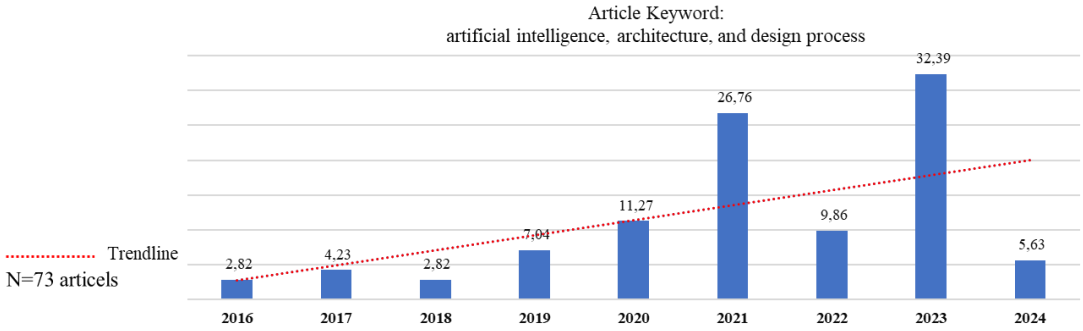


Fig. 3 Twelve Domains That Demonstrate the Relationship Between AI and Architectural Design

Conducting The Review Literature

Manual checking is carried out by identifying the research title and its relevance to the use of keywords. This process aims to; (1) avoid duplication (binary) of articles, and (2) ensure that the main terminology "architecture" is the science of art and building design, not computer architecture in the field of computer science. This stage succeeded in selecting 146 articles that were identified as binary and 281 articles that lacked relevance, leaving 73 relevant articles (Figure. 4). Figure 4 shows the distribution and research trends of the 73 articles that experienced an increase (red trendline), where the highest publication in 2023 was 23 articles (32.39%). The number of articles in 2024 will probably increase, because searches were only carried out from January to May 2024, namely when this research was compiled and written.



Year of Publication	2016	2017	2018	2019	2020	2021	2022	2023	2024
Number of articles	2	3	2	5	8	19	7	23	4*)

*) search from January to May 2024

Fig. 4. The Distribution and Research Trends of the 73 Relevant Articles

Analysis and Writing the Review

During the analysis process, 56 out of 73 articles were found to be open access. These articles were carefully reviewed for their abstract, introduction, and research findings. The analysis involved activities aimed at understanding and evaluating the content of the literature. The results of the analysis categorized 48 articles as supporting the discussion of research as evidence, and eight articles as supporting research gaps (refer to Appendix A). These articles were systematically written in the literature review section. The literature review was structured based on the results of the literature analysis. Eight articles were synthesized to compare previous sources in filling and explaining research gaps. The remaining 48 articles were used to help readers understand the research topic based on supporting evidence from previous research results.

RESULTS AND DISCUSSION

Overview of the Development of Digital AI Technology

Artificial Intelligence (AI) technology has been widely integrated into various aspects of human life, including social, economic, educational, and healthcare sectors. It enhances effectiveness, efficiency, and integration in

professional tasks. AI was first defined as the science and technique of creating intelligent machines by Marvin Minsky and John McCarthy at Stanford University in 1956 (Haenlein & Kaplan, 2019). AI is characterized by its ability to "analyze" and "take action" autonomously to achieve specific goals and is designed to replicate human-like thought processes (De Spiegeleire & Sweijs, 2017). AI mimics the workings of the human brain to perform functions such as perception, reasoning, learning, planning, prediction, and control (Fan et al., 2020). It prioritizes essential information, minimizing errors and maximizing output. The Turing Test, introduced by Alan Turing in 1950, assesses whether machines can think by determining if people can distinguish between human and computer responses (Turing, 1950). This test suggests that machines and humans exhibit similar intelligence, albeit through different thought processes. AI can be categorized into four areas: (1) acting humanely, (2) thinking humanely, (3) reasoning, and (4) acting rationally (S. J. , Russell & Norvig, 2010). These categories encompass the machine's ability to imitate human behaviour, replicate human thought processes, apply logical reasoning, and optimize actions for the best outcomes.

In conclusion, the ongoing development of AI aims to create new forms of interaction between humans and digital technology, offering alternative ways to enhance human work. However, the use of the term 'human-like way of thinking' in AI is a topic of debate, raising concerns about its potential impact on human existence, particularly in the world of work.

Overview of Architectural Work Stages

In general, the architectural workflow consists of design work and construction work. The design process in an architectural studio traditionally consists of (1) Programming Phases; (2) Schematic Design Phase; (3) Design development phase; and (4) Construction Documents Phase (Soliman, 2017), also including the Detail Design and Testing Solutions phases (Hettithanthri et al., 2023) and expanded in more detail into ten phases (Holzmann & Lechiara, 2022). However, the design process described by Hettithanthr and Holzmann is a process that is commonly carried out in the context of architectural studio class learning pedagogy, so this research adds two further processes, namely Construction Bidding and Construction Observation to show the architect's overall involvement in the design process through to the construction process (Figure 5).

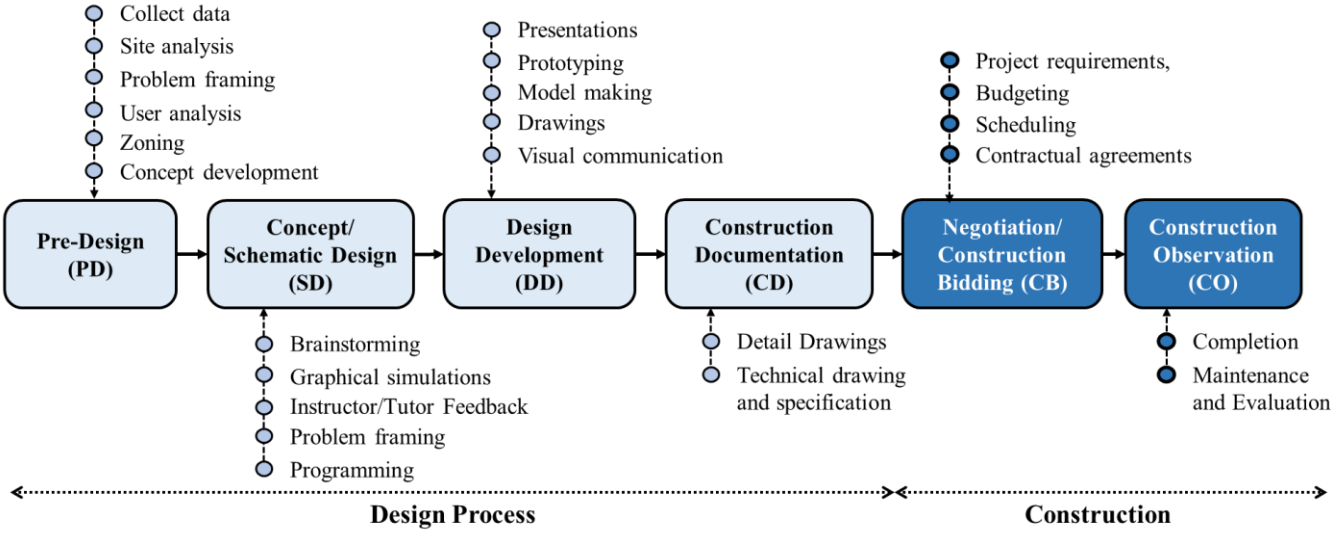


Fig. 5. Stages of Architectural Work

According to figure 5, at the Pre-design (PD) stage, the architect begins design activities by compiling a framework for the space requirements program. This process involves collecting information and data about building regulations, the number of rooms, room functions, room area, and other specifications. This process also requires the architect's ability to see existing conditions at the planning location to identify green areas, topography, infrastructure, accessibility, and so on. The second stage is Concept/Schematic design (SD), namely creating a design concept. This stage is also called a crucial stage because architects are required to provide their design concepts and concepts authentically. The consumption of an architect's time, energy, and thoughts is entirely drained at this stage. The architect will start expressing his ideas through scribbled hand sketches and by studying mock-ups to find various possible alternative design ideas that are most suitable. The results of the space program data collection in the first stage are applied and adapted to the design idea so that there is conformity. The next stage is design development (DD). The process of translating design ideas into design documents occurs at this stage. The architect's scribbled

ideas will be continued into several measurable drawings, which will be approved as a guide in building or construction activities. The final stage in the design process is construction documentation (CD), in which the architect creates several detailed construction drawings, including technical drawings and specifications that the contractor will use to build the project.

Next is the involvement of the architect in the construction process. Construction work requires architects to control the implementation of work in the field. This process aims to ensure no errors or undesirable changes to the design. Negotiation or auction process (Bidding Process/CB). Construction documents worked on at the construction documentation stage are sent to the contractor to make an offer regarding construction costs. This bidding process allows clients to select a contractor that fits their needs and budget. The final stage is construction observation (CO). This stage involves the physical implementation of the architectural design. The architect may supervise construction to ensure the project goes according to plan.

Artificial Intelligence in Architectural Work

Digital technology has been widely used as a design tool in architecture. Drawing software, for instance, has been developed to expedite the architectural design process. Tasks like creating working drawing documents, which used to be time-consuming when done manually, can now be completed more efficiently and quickly. The use of digital design tools allows architects to leverage the full potential of computers and explore new possibilities for architectural ideas (Tedjosaputro, 2020). The rapid advancement of AI has not only led to significant changes but has also revolutionized innovative design approaches and practices in architectural design (Zheng et al., 2023). The integration of Artificial Intelligence in architectural work provides unprecedented flexibility and the opportunity to introduce and test new parameters, reshaping the way architects work (Lukovich, 2023). This transformative power of AI is evident through the emergence of various AI products specifically designed for architects. This research has identified and summarized approximately 23 types of AI-generated platforms in the form of widely-used websites in architectural work (Appendix B).

Apart from the websites above, several researchers also use AI machine learning mechanisms to support the design process. Two branches of AI are popularly used in architectural work: machine learning (ML) and deep learning (DL). ML is a machine learning system created to carry out work independently and learn and process data for specific purposes. ML can also be defined as building a computer system that automatically improves performance with experience and implementing a learning process. ML in the architectural discipline has been widely used for decision-making and prediction systems, which provide opportunities to improve the reciprocal relationship between machines and architects in architectural work (Özerol & Arslan Selçuk, 2022). The work covers various issues, such as sustainability architecture, structures, intelligent building design, space design, and digital fabrication (Topuz & Çakici Alp, 2023). Meanwhile, DL is a part of ML suitable for handling larger data sets with higher complexity. DL is usually used for complex tasks such as image and speech recognition, natural language processing, and autonomous systems (Taye, 2023). DL algorithms have generative capabilities that allow the system to explore various possibilities without predetermined limitations, thus having the potential to produce innovative and unexpected architectural designs (Mrosla L. et al., 2019).

AI algorithms like the Deep Neural Network (DNN) and the Generative Adversarial Network (GAN) are not just tools, but creative partners in architectural design. For instance, the DNN algorithm creates floor plans by extracting designs into building mass blocks (Ko et al., 2023). It also carries out conceptual building designs, such as evaluating and composing building mass blocks (As et al., 2018). DNN, designed to process information like the human brain, is a powerful tool in architectural design. Another notable algorithm is the GAN, which produces building plans (Chaillou, 2020). GANs offer a data-driven approach to automatically generate architectural space layouts, enabling architects to define building boundaries and bubble diagrams as vector data architectural floor plans (Nauata et al., 2020); (Aalaei et al., 2023) (Figure 6). GANs have also been used in architectural design tasks such as creating and analyzing 2D and 3D designs of specific architectural styles (Newton, 2019). For example case, Aalaei, M

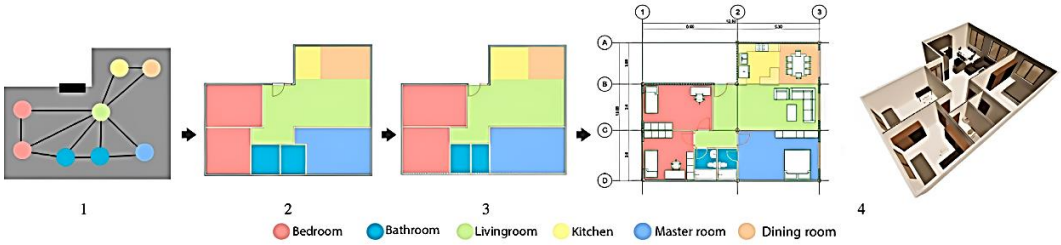


Fig. 6. An Iterative and Collaborative Process Between Humans and Machines in Creating Architectural Floor Plans
Source: Aalaei, M, et al., 2023

The Role of AI in Phrase Pre-Design (PD)

Preliminary design involves the architect creating various space requirements programs. Architects gather important information such as permit documents, building regulations, number and function of rooms, room sizes, and other specifications. This process also entails collecting and reviewing several building regulation documents and physically inspecting the existing conditions on site. This traditional method can impact data accuracy and be time-consuming. Nowadays, AI products such as Archistar (https://www.archistar.ai/), UpCodes (https://up.codes/), TestFit AI (https://www.testfit.io/), and Aino (https://aino.world/) can streamline the design preparation process. These AI platforms optimize the analysis of building regulations with a rapid and accurate iteration process. For instance, architects can input project criteria, and the AI product will quickly provide spatial data and alternative 2D and 3D models, or automatically verify building regulations and codes. Pre-design phase tasks such as data collection, site analysis, data analysis, zoning, problem framing, and concept development are complex initial processes that can benefit from using AI.

Previously, architects worked independently at this stage, but AI can now provide easier data access and help architects conduct data analysis more effectively and precisely. Yudhanta and Hadinata, (2024) state that computational techniques and artificial intelligence (AI) in the design phase can transform complex processes into measurable and evaluable processes. In their study, designing a house on a 100 m² plot requires a challenge, strategic analysis, and decision-making from the architect. Artificial intelligence (AI) simplifies the pre-design stage by analysing geometric shapes, sunlight orientation, and space configuration while generating exterior and interior visualisations. This significantly accelerates the traditional analysis process. Artificial intelligence (AI) simplifies the pre-design stage by analyzing geometric shapes, sunlight orientation, and space configuration, while also generating exterior and interior visualizations. This significantly speeds up what is typically a lengthy analysis process. Generative AI, for example, can assist architects by creating initial conceptual references based on their sketches, encouraging divergent thinking in the design process, and facilitating collaboration to develop more efficient design proposals (Liu & Zhao, 2023). AI is critical in the pre-design stage, enabling architects to work more effectively and efficiently. Initial preparatory work, such as site data collection, can be optimized by leveraging and analyzing data available on AI platforms. This approach offers practical steps and can lead to reduced initial operational costs. Furthermore, AI can assist architects in data analysis, which often involves complex thinking, by providing comprehensive and informative data to guide their analytical work.

In short, AI is transforming the preliminary design phase in architecture by streamlining the design preparation process through optimized building regulation analysis. It also highlights the role of generative AI in assisting architects in creating initial conceptual references based on their needs and encouraging divergent thinking in the design process.

AI Integration in the Schematic/Conceptual Design (SD)

The second stage involves creating a design concept or schematic design, which is time-consuming. Architects must ensure that the concept can meet all design requirements and is not solely focused on aesthetics. There is ongoing debate about the use of traditional methods in the design process, with some arguing for greater integration of architectural design with environmental context, construction work, electrical mechanics, and other factors. Over the past five years, the use of AI in solving architectural conceptual design problems has increased by up to 85% (Castro Pena et al., 2021). This trend necessitates high-level integration of thinking, where generative design is presented as a solution (Agkathidis, 2015). Generative design is a design exploration process that relies on digital computing, and its use is rapidly growing. The process begins by entering design requirements into generative design software, along with parameters such as space requirements, materials, construction method, and cost. In this scenario, the AI system is capable of generating various conceptual designs by interpreting and understanding the program requirements provided by the text-to-task model, which translates the textual input (program requirements) into actionable tasks, such as creating design options (Ghimire et al., 2024a). In the Museum of the Future – Dubai, UAE, a case study conducted by Killa Design and Buro Happold, a custom AI-driven generative design engine was utilized to explore various façade geometries and layouts. Designers provided high-level program requirements and environmental data, enabling the AI to generate thousands of conceptual iterations. This innovative approach significantly shortened the design process from months to weeks by automating the exploration and evaluation phases.

Generative design can also test and analyze the success and failure of a project. The use of generative design has been suggested as a new approach that allows architects to leverage computational capabilities for exploring alternative designs (Mukkavaara & Sandberg, 2020). For instance, platforms like Arkdesign.AI (https://arkdesign.ai/) and https://stanislaschaillou.com/ can be utilized to create design schemes and alternatives. By inputting simple data

on the Arkdesign.AI website, the platform swiftly provided numerous alternative floor plan layout schemes that could be chosen based on design preferences. Meanwhile, stanislaschaillou.com presents a more concise and user-friendly display of schematic building plan designs, visually demonstrating the placement of windows, entrances, voids, and space functions on the prepared basic plan pattern, facilitating the quick generation of space designs (see Figure 7).

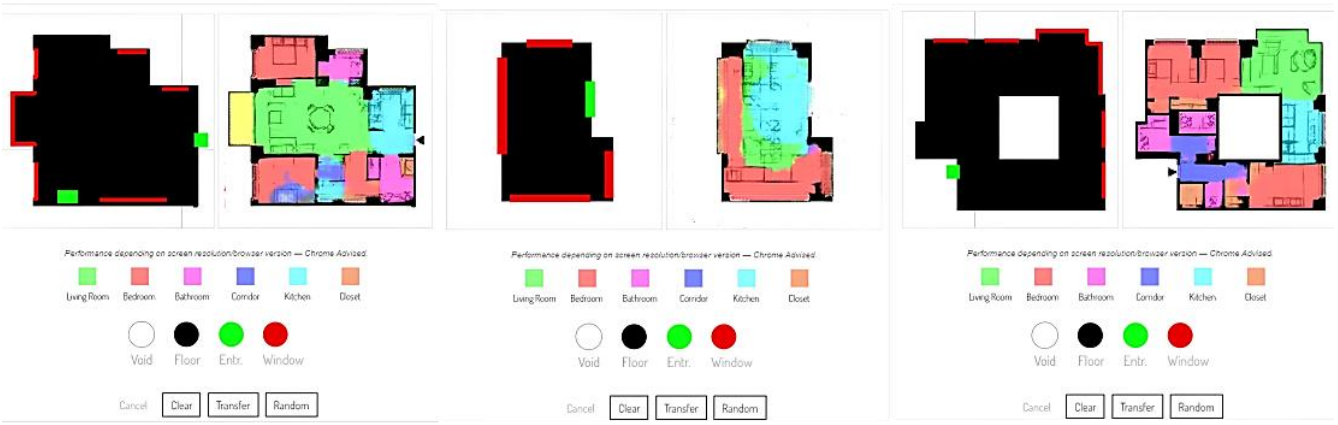


Fig. 7. Create Design Schemes and Alternatives of Floor Plans Using The Stanislaschaillou Platform

In this phase, architects must also prepare space programs (programming), such as analyzing space requirements, identifying types of space and activities, and considering technical aspects of space. These steps are essential before the design is developed into a final design. With AI platforms like Ark.Ai (https://arkdesign.ai/) and Architechtures (https://architechtures.com/en), architects don't need to start all processes manually from scratch. This AI platform helps determine design choices based on schemes generated by AI. The AI platform will automatically analyze the input space requirement data, providing detailed information regarding space requirements, space types, and technical considerations. Architects can then use the results of this AI analysis to process and develop further with drawing software. Apart from that, the complexity that architects have carried out in creating floor schemes can also be automated using AI from textual descriptions (Jain et al., 2018). This shows the potential to change the way building plans are created by utilizing descriptions provided by clients (Figure 8).

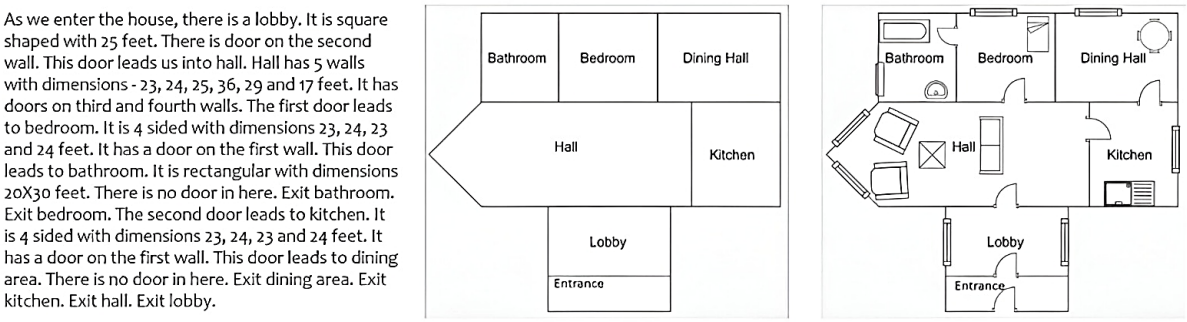


Fig. 8. Illustration of Floor Plan Generation from Textual Description
Source: Jain et al., 2018

Therefore, the AI's role in conceptual design is to assist architects in defining design criteria like space needs, materials, construction techniques, and expenses. The AI platform is capable of producing multiple conceptual designs and proposing design alternatives. Additionally, generative design can assess and evaluate project outcomes. This strategy is proposed as a novel approach that enables architects to utilize computational capabilities in exploring different design options. While there are ongoing debates about the challenges of using generative design in the design process, it is foreseeable that individuals may be able to design their own homes in the future. This potential scenario could pose a threat to the role of architects and blur the boundaries of creativity required in this conceptual stage of design.

AI Generative Optimization in the Design Development Phase (DD)

In the design development phase, architects develop detailed drawings, visualize in 2D and 3D, and create physical models such as mockups or video visualization. They also explain in detail through detailed drawings

developed to express the design solution. The main focus is to express design solutions to clients through architectural drawings, models, and 3D visualization. Several work items at this stage, such as layout design, structural design, 3D shape design, facade design, and image expression based on objective and subjective conditions, have involved significant use of generative AI in the process (Li et al., 2024). For example, Figure 9 shows the results of creating a visual representation of a building design using the generative AI platform NewArc.ai (https://www.newarc.ai/). By submitting rough sketches to this platform, architects can generate various visual options by entering text prompts or using text-to-image methods. Compared to the traditional approach, this approach provides convenience and enhances the quality of representative images for the design development stage. Generative AI also helps architects create 3D drawings and models, simplifying the production of animations and virtual tours, thus eliminating the need for expensive and complex software and saving time and costs (Yıldırım, 2022). Traditional methods for producing 2D and 3D visualizations require costly digital software and powerful tools, often taking days or weeks to process and hindering client interactions. In contrast, generative AI processes 2D and 3D images quickly and efficiently, offering significant advantages for architects during the design development stage. This allows for faster completion of visual image processing and facilitates practical discussions with clients, enabling the presentation of various 2D design visualizations, 3D models, and virtual videos for visual communication and presentation.

Fig. 9. 2D Visual Image of A Building Design Using the Generative AI Platform NewArc.ai.

Although the role of AI in design development is growing, architects still have to define their role. AI primarily generates design alternatives based on input data provided by the architect, so the complexity of this data is critical to the quality of the design produced by AI. Architects begin the design process by providing data to AI, evaluating the ideas generated, and refining the final design based on these AI-generated concepts (Tanugraha, 2023). In conclusion, generative AI enhances the design development phase for architects by enabling rapid creation of 2D and 3d visuals, models, and animations. Generative AI reduces the need for expensive software, saves time and money, and improves client communication by providing various design options. In addition, the traditional design presentation process that utilises 2D/3D drawings and physical models has limitations, especially in creating a shared understanding between architects and clients. A promising solution is Extended Reality (XR) technologies, such as Virtual Reality (VR), which provide immersive spatial experiences. This technology can enhance visual communication, improve spatial exploration, and encourage more authentic and participatory design collaboration in the design development phase.

AI to Create Construction Drawing Documents (CD)

This stage focuses on creating various construction documents including architecturals drawing dan structurals drawing such as site plan, floor plans, sections, elevations, details, structural design, mechanical and electrical plans, etc. The construction drawing documents produced at this stage continue the conceptual and design development stages. This construction document will be used as a technical guide for carrying out construction work in the field. The accuracy and completeness of drawings is an absolute requirement that often takes architects and their drafting teams several months to complete. AI can process data from various sources, such as 2D images, 3D models, and BIM (Building Information Modeling) data, using machine learning and deep learning algorithms to produce accurate technical drawings and construction drawings. AI, like Generative Adversarial Networks (GAN), are machine learning models that are highly effective in generating images, including technical drawings such as floor plans, mechanical diagrams, electrical diagrams, pipe diagrams, and section views. (Ghimire et al., 2024b).

Currently, architects have widely used various platforms and software that are integrated with AI, such as AutoCAD with AI features, Revit and Dynamo, ArchiCAD with Grasshopper, or SketchUp with AI plugins, to create construction document drawings. The software offers automation in design tasks and shop drawing production. This method provides benefits to architects in terms of reducing processing time, increasing drawing accuracy, and ensuring technical integration between drawing and modeling. For example, using AutoCAD drawing software

typically involves the architect's technical skills to operate the software according to design needs. However, when AutoCAD integrates AI to automate the creation of technical drawings, it significantly enhances the design process through advanced features (Figure 10). AutoCAD leverages AI and machine learning to streamline repetitive tasks, improve accuracy, and increase productivity. This collaboration allows for more efficient workflows, better design optimization, and enhanced project collaboration. For example, the case study Lake Residence – Lake Bled, Slovenia, by Architect Tim Fu used the help of Autodesk Revit AI, where AI addons automatically produced drawings such as plans, elevations, sections, dimensions, and technical annotations, with complete coordinate precision. This case study shows that creating a CD that usually takes several weeks can be completed in a few days, with minimal manual intervention.

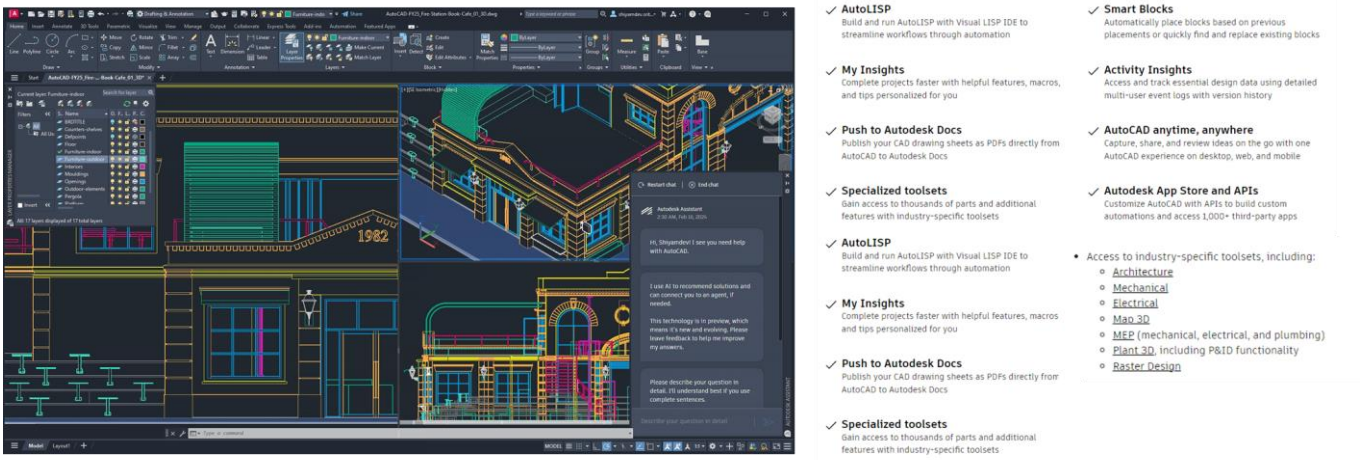


Fig. 10. Autodesk AutoCAD Software Features Include Industry-Specific Toolsets, New Automation, and Insights by Using AI
Source: https://www.autodesk.com/products/autocad/features

Potential of Negotiation by AI in Construction Bidding (CB)

In architectural work, the negotiation process is crucial for reaching agreements between architects and stakeholders involved in a project. Various aspects, such as project requirements, design, budget, scheduling, permits, and contractual agreements, are discussed during negotiation. The negotiation skills required by architects are complex as they involve human emotions and effective communication. Nevertheless, there is increasing interest in leveraging AI technology for negotiation practices. Studies have highlighted the potential of AI in assisting with negotiation tasks, teaching negotiation skills, and even facilitating automated negotiations between AI and humans (Dinnar et al., 2021). The future of architectural work is reassuring with AI's potential to enhance negotiation outcomes' overall efficiency and accuracy. AI can aid in streamlining tedious negotiation tasks, reducing cognitive errors, and ensuring better negotiation outcomes (Dobrijevic & Djokovic, 2020). Platforms and software, such as the Pocket Negotiator (PN) and IAGO Negotiation platform, have been developed to support negotiation processes. The PN software, for instance, assists in various negotiation phases, models negotiating opponents, and supports auctions with visual representations (Jonker et al., 2017). On the other hand, the IAGO negotiation platform utilizes automated agents programmed to simulate human-like emotions and behaviors for building rapport and influencing negotiation outcomes (Mell & Gratch, 2017). While the application of these technologies in architectural projects is yet to be fully realized, the concept of integrating AI in negotiation processes holds potential for enhancing the effectiveness of architects' negotiation work in the future.

In short, negotiation in architectural work and the potential of AI technology to enhance negotiation outcomes. Negotiation skills that are impossible to replace by technology are now being taken over by AI. Specific platforms and software, such as the Pocket Negotiator and IAGO Negotiation platform, were developed to support negotiation processes and simulate human-like emotions and behaviors to influence negotiation outcomes.

AI in Construction Projects Observation (CO)

The use of AI in construction observation activities has become commonplace today. The emergence of AI technology has significantly revolutionized architectural work, introducing new construction techniques and improving project management (J. , Petrovic et al., 2021). AI is a powerful tool that can simplify work processes and contribute to project success in all aspects of project management, especially in estimation, control, scheduling, cost and risk management (Holzmann & Lechiara, 2022). The automation of architectural work with digital technology,

machines and robots presents many possibilities. In practice, tasks usually carried out by architects, such as construction, can now be carried out by robots or machines. AI plays a crucial role in ensuring the quality of construction activities by using computer vision systems that automatically inspect and evaluate surfaces for defects or conformity to design specifications (Ivanova et al., 2023). This process is instrumental in ensuring that construction meets established design and quality standards, thereby maintaining the integrity of the project. AI can monitor project progress using cameras and drones with image recognition algorithms, ensuring projects run according to schedule and specifications. AI can also detect construction errors, such as improper installation or structural defects, through analysis of visual and sensory data, enabling corrective action by the architect or contractor. AI is used for tasks such as grading materials, monitoring worker attendance, supervising heavy equipment use, and ensuring work safety and security (J. Lee & Lee, 2023) (Figure 11).

Fig. 11. The AI Model for Detecting Falls Among Workers was Demonstrated at the Construction Site
Source: J. Lee and Lee, 2023

AI has revolutionized architectural work by introducing new construction techniques and enhancing project management. It can streamline work processes and contribute to project success in estimation, control, scheduling, cost, and risk management. AI integrated with machines and robots can carry out technical tasks in construction projects effectively and efficiently. Furthermore, AI plays a vital role in overseeing construction activities, tracking project progress, identifying errors, ensuring compliance with safety standards, and assessing building maintenance and performance. A prominent example of AI technology used in the Architecture, Engineering, and Construction (AEC) industry is Digital Twin (DT) technology. The Sydney Opera House, for instance, has implemented Digital Twin technology to better evaluate energy consumption, enhance facility management, and conduct more accurate operational analyses (Mousavi et al., 2024). This application greatly assists in managing the complex tasks within the AEC sector.

Discussion

This study has successfully demonstrated that AI has the capacity to handle all aspects of architectural work. It can engage in technical architectural tasks, such as pre-design and design development, as well as more complex and creative design work, including schematic design, negotiations, and construction observation. This lends weight to the argument that AI may eventually replace architects. Therefore, will architectural jobs be replaced by AI? Several thoughts from practitioners and researchers reject this argument. Technology such as AI cannot replace architectural work because an architect's work is more than just utilizing technology. Even though AI has shown attractive and creative aspects that resemble humans (architects) in some design specialties, it cannot yet replace the unique aspects such as authenticity and harmony that architects possess (Zhang et al., 2023). Computers require human roles and cannot work independently (Kołata & Zierke, 2021). Machines with a high level of intelligence, such as AI, may be able to replace the role of humans in industry, but the creativity and spirituality humans possess cannot be replaced at all in work (Yang, 2018).

Many consider the worry that technology will replace human jobs as something too far-fetched to worry about because the benefits provided by technology are far more critical to appreciate than to debate about them. Digital technology in architectural work makes the architectural design process easier and more efficient, but it needs to be used wisely. The collaboration between architects and generative AI places a strong emphasis on the integral role of the architect in the design process (Ayman et al., 2024). However, technological challenges and threats also need to be anticipated because the pace of technological development is challenging to predict, especially the destructive impacts that are always evident. Attention to disruption as a transitional stage of technological events requires consequences that need to be prepared by humans as anticipatory steps to reduce the negative impacts they cause (Kivimaa et al., 2021). For this reason, architects must prepare themselves with reliable abilities. Architects must master science and technology to be able to become leaders in controlling technology because it is realized that AI

as a new technology has enabled designers (architects) to explore new concepts, foster creativity, and continue to improve and reach the boundaries of design (Ko et al., 2023). In general, workers (including architects) need to adapt to the dominance of AI by developing new skills, for example, the ability to carry out data analysis and think critically to anticipate the domination of work by AI (Ofosu-Ampong, 2024), where collaborative integration between architects and AI is needed to suppress concerns about the replacement of the role of architects by AI (Desouki et al., 2023). Even so, predictions about the impact of AI in the architectural profession are still ongoing and cannot yet be concluded with certainty. Still, the role of AI in architecture does not challenge the core ideas of design thinking but rather strengthens them (Shah & Sahastrabuddhe, 2024)

Referring to this discussion, this article wants to estimate that technology may shift the role of architects in the future. In this context, the words "shifting roles" differ from "replacing roles." Shifting roles is defined as a stage of work that was previously entirely carried out by the architect, then shifting to an actor who collaborates with technology, thereby increasing work flexibility. These predictions indicate changes in "new design interactions" between architects and technology. Technology that is tightly integrated with architects will drive incremental changes in work productivity and flexibility. However, AI does not function as an independent intelligence, and architects still retain full control over architectural work. The presence of AI introduces a new dynamic in the interaction between humans and technology. This shift is inevitable and may ultimately become a necessity in the future. Architects no longer rely on conventional methods in their design process, and AI technology must be positioned as a tool or medium to help work become more optimal (Figure. 12).

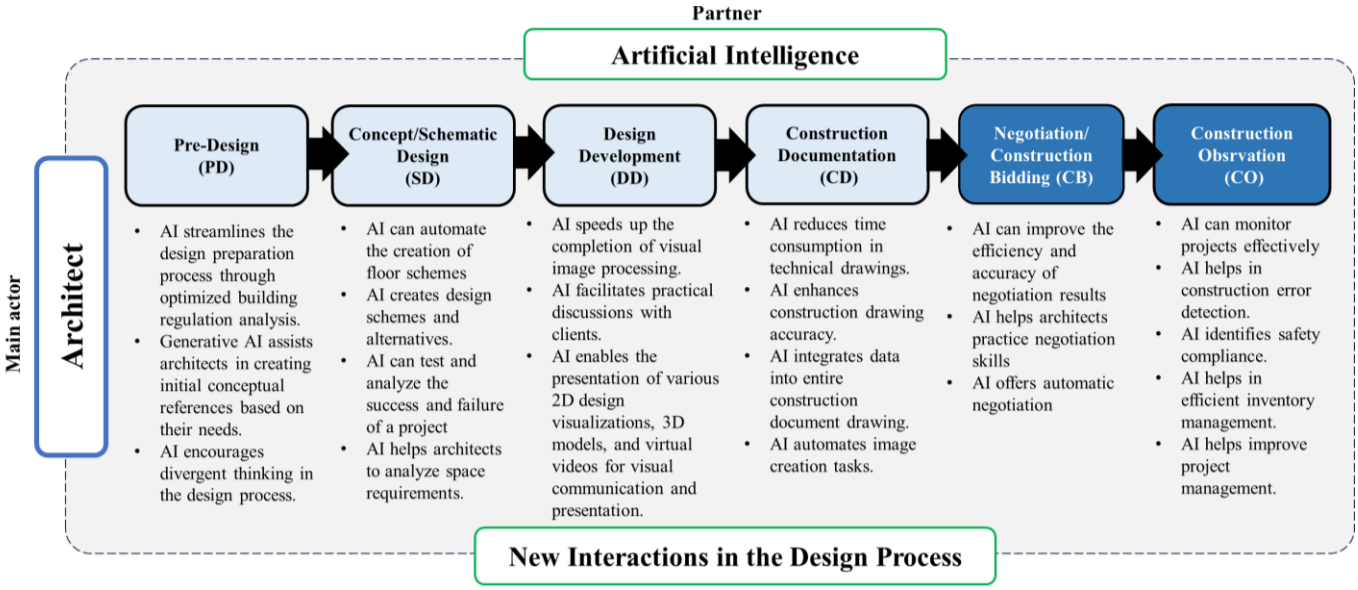


Fig. 12. The Illustration of New Interactions in the Design Process between Architects and AI

CONCLUSION

This article discusses the relationship between architects and artificial intelligence (AI) in architectural design. The advancement of AI has brought new ways of interacting at all stages of architectural work. AI can now handle design tasks requiring creativity and complexity. It is becoming indispensable for future architects. If architects incorporate AI technology from the beginning to the end of a project, it can improve efficiency and effectiveness, while addressing challenges and limitations often encountered in traditional work, such as accuracy, integration, time, and cost. AI's ability to collect, analyze, and generate various design solutions from data is highly advantageous for architectural work. While AI makes architectural work more accessible, it also requires a high level of reliance on technology. The extensive design process, which involves high-level thinking and integration, necessitates "collaboration" between technology and architects to produce creative and innovative architectural works. Therefore, unlocking AI's significant potential is not just a necessity, but an opportunity for architects to have a deep understanding of AI and effectively utilize it to remain relevant in the future. Mastery of digital computing skills is another essential competency for architects to compete in the design industry. Even though this article suggests that AI cannot fully replace architects' work as it cannot function independently, architects who comprehend and master AI will continue to play a central role in design work. This situation certainly poses challenges and threats to the architectural profession, particularly for architects who are accustomed to traditional working methods.

Some limitations in this article include limiting the literature collection to open-access articles, thereby limiting the richness and completeness of relevant information. In addition, this article is still exploratory. It needs to provide

examples of technical projects as case studies to clarify the role of AI in architectural design work in more detail. Therefore, this article suggests further research that examines case studies of architectural projects that fully leverage AI. Additionally, this article has great potential to be followed up in the future, as the massive development of AI is expected to significantly impact changes in architectural work, opening up new possibilities and exciting opportunities for architects.

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Appendix A.

No	Categories	Statement conclusion about AI in architecture field	Research's Gap	Authors
1	• Artificial Intelligence in Architecture, • Human-centered	• AI is reshaping the architectural discipline. • This research highlights a shift from talking about robots to talking about artificial intelligence in architecture. • Discussion of the possibility of adopting artificial intelligence in the construction industry and the architectural design process.	• Although discussions about artificial intelligence in architecture are increasing, there is still a need to explore further its impact on the design process and human creativity. • More in-depth research is needed to explore how architects and designers can adapt to technological change	Picon, A. (2020)
2	• Artificial intelligence applied to conceptual design in architecture	• AI can solve conceptual design problems in finding innovative and creative forms. • The dominant types of AI approaches in architectural conceptual design are EC (Evolutionary computing) and GA (Genetic Algorithms).	• Further research is needed to explore how the integration of artificial intelligence technology with architectural design can improve efficiency, creativity and sustainability in the design process	Pena, M.L.C., et al (2021)
3	• Artificial Intelligence in Architecture • New Paradigm in architecture	• AI provides a new paradigm in architectural work. • AI helps find solutions and alternatives in solving design problems. • The use of AI in architecture is no longer the realm of utopia or science fiction but an increasingly actual reality. • The development of AI has profound consequences for the education of future architects.	• Architects still pay little attention to the new paradigm of AI in architecture. • There is a need for more research and attention to integrating AI in architecture, given its complexity and potential impact. • The necessity for further research to comprehend the effective application of AI in the architectural design process is a pressing matter that requires immediate action.	Lukovich, T. (2023)
4	• Human-centered • Artificial intelligence in architecture, engineering, construction industry	• AI to improve design efficiency, such as creating automated modeling processes (intelligent simulation). • AI replaces conventional modeling processes and facilitates the architectural design process. • AI improves architectural, civil, and construction work practices. • AI has great potential to enhance the knowledge and skills of architects.	• Develop AI models more responsive to individual or group human preferences and needs. • Integration of AI with ethics and social responsibility. • Interdisciplinary collaboration • Development of more adaptive AI models.	Rafsanjani, H.N., and Nabizadeh, A.H. (2023)
5	• Artificial intelligence in architecture and it's applications	• The use of AI in architecture is increasing significantly. • AI enables architects to analyze and optimize complex design problems. • AI offers new avenues for innovation and creativity in architectural practice.	• Explore the practical implementation of AI in architectural projects. • Delve into the specific applications of AI from each sub-field of architectural work.	Bölek, B., et al. (2023)
6	• AI Image Generator • Architectural Field	• Utilization of AI for image visualization production needs. • AI will greatly help architectural work in	• Development of an AI image generator specifically for architectural needs • Evaluate the quality of design results	Enjellina, et al (2023)

No	Categories	Statement conclusion about AI in architecture field	Research's Gap	Authors
		visualizing ideas into images.	produced by the AI image generator • The influence of using AI image generators on creativity and innovation in architectural design	
6	• Genertive Design Methodolgy: • Human Collaboration & AI	• AI in the architectural design process can improve design efficiency, accuracy, and quality. • AI enables architects and designers to explore various design options quickly.	• There is a need for further research to explore the potential for applying AI in architectural design in more depth. • Further research is needed to identify obstacles to implementing AI in architectural design practice	Hassab, A., Abdallah, M., and Abdelmohsen, S. (2023)
7	• Artificial Intelligence's Effects • Profession of Architecture	• AI does not challenge the core ideas of design thinking but rather strengthens them. • AI helps architects to produce more efficient and innovative building designs. • AI is driving the architectural profession forward in exploring new avenues during the design process.	• Further research with a larger sample is needed to gain a more comprehensive understanding of AI's influence in the architecture, engineering, and and construction industries.	Shah, T. and Sahastrabudde, S. (2024)
8	• Artificial Intelligence in Architecture • Architectural Design Process	• AI contributes to improving the performance of the architectural design process stages. • AI enhances creativity and enables the creation of innovative solutions. • AI presents information.	• There are still some tasks that AI cannot handle well, such as human creative processes. • Further research is still needed to optimize the integration of AI in the entire architectural design process.	Matter, M.N., and Gado, N.G. (2024)

Appendix B.

No	AI's product	Function	Needs in Architectural Work
1	Mid-Journey in Architecture (https://www.maket.ai//)	*AI for visualization tools and Concept Design.*	• Perform 3D rendering from photos or sketches
2	Fotor in Architecture (https://www.fotor.com/features /ai architecture/)	*Architecture visualization tools*	• Review real-time projects with natural elements
3	Jasper Art (https://www.jasper.ai/)	*Impressive visualizations*	• Create photo-realistic images.
4	Stable Diffusion (https://ai-pro.org/)	*Open Sources AI Architecture Generator*	• Perform text and image-oriented visualization
5	Maket.AI (https://www.maket.ai/)	*AI Generator for Architectural Plan Design*	• Offer a variety of design options by defining design constraints and goals
6	Architectures (https://architechtures.com/en)	*AI Generator for Architectural Planning and Design/AI for Residential Planning.*	• Made various changes to design styles and features.
7	NightCafe in Architecture (https://creator.nightcafe.studio/)	*Text-Based Visualization + Video Content Provision*	• Create creative design works with surrealist characteristics.
8	Kaedim (https://www.kaedim3d.com/)	*AI Generator for Architectural Modeling*	• Making changes to parameters such as light, texture, and materials, the architect can produce the desired image output.
9	Arko.AI (https://arko.ai/privacy)	*Artificial Intelligence Generator Compatible with Architecture Software*	• Create floor plan production quickly,
10	Dream (https://womboaiartgenerator.co m/)	*AI Architecture Generator*	• Creating various design styles and providing special solutions in the areas of material and material metering and cost estimation
11	Arkdesign.AI (https://arkdesign.ai/)	*AI for Schematic Designs.*	• Provides a variety of flexible design options.
12	Archistar (https://academy.archistar.ai/)	*AI Architecture Generator for Site Analysis*	• Analyze site conditions and client needs
13	Hypar (https://hypar.io/)	*AI Architecture Generator*	• Offers a wide choice of designs that perfectly harmonize form and function.
14	Foyer Neo (https://foyr.com/)	*AI Architecture Generator for Interior Design*	• Draw schematic and conceptual maps in the fastest time.
15	PlanFinder.AI (https://www.planfinder.xyz/)	*AI Architecture Generator*	• Produce abstract, creative, and aesthetic architectural drawings.

No	AI's product	Function	Needs in Architectural Work
16	Spacemaker - Smarter Decision-Making	*AI software empowering architects, urban planners, and real estate developers*	• Explore creative concepts and visualize ideas very quickly.
17	Veras (https://www.evolvelab.io/veras)	*AI for Rendering.*	• Create detailed documentation of 3D models to architects and clients accurately and realistically.
18	Autodesk Forma	*AI for Sustainable Design.*	• Easily create countless design ideas while changing the geometry of 3D Models.
19	TestFit AI (https://www.testfit.io/roles/architects)	*AI for architects and building professionals*	• Create 3D geometric integrity when rendering context and materials
20	ReRender. AI (https://rerenderai.com/)	*Photorealistic AI Renders for Architectural Design*	• Create visualizations and renderings of architectural projects by uploading textual content and selecting the art style according to the architect's wishes
21	mnml.ai https://mnml.ai/	*Architecture AI tools*	• Quickly produce schematic designs that are optimized and tailored to specific project needs.
22	Promeai (https://www.promeai.com/)	*AI for image generation and editing image*	• Create optimized floor plans quickly and efficiently
23	Strayos (https://www.strayos.com/site-analysis-ai.html)	*AI for site analysis*	• Perform site analysis, project status assessment, and rule-based conceptual design.