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Viewpoints of the Architects on Using Artificial Intelligence in Green Architectural Design: A Case Study in the City of Kerman, Iran

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Abstract

In architecture, AI can perform many tasks during the architectural design process, so it is necessary to understand this technology and its advantages and disadvantages, especially for those concerned with environmental and sustainable aspects. There are gaps and ambiguities in relation to the effect of using AI in architecture, especially when it comes to the principles of the green architecture, particularly in Iran. Therefore, the current study was formulated to determine the possibility of AI in supporting green architecture design, to determine the possibility of AI in achieving the principles of green architecture, to examine the architects' viewpoints regarding the role of AI in achieving the principles of green architecture by using a questionnaire, and to determine the most common AI programs used by architects the most. To address the research objectives, a questionnaire was adopted, and back-to-back translated, and distributed among 46 architects who worked in Kerman city, Iran. The data was collected during October 2024, and to analyze, SPSS Version 25 was used. The results of the study showed that to a great extent, AI can support green architecture design because majority of the respondents confirmed that AI can give multiple alternatives to environmental treatments and can help the designer make design decisions to achieve the green architecture principles. Overall, it was concluded that AI can achieve principles of green architecture.

Keywords: artificial intelligence, architecture, green architecture, Ai-design

1. Background

A collection of computational techniques known as artificial intelligence (AI) allow systems to do a wide range of tasks that were previously thought to require human intelligence (Allam, 2016). AI is capable of performing a wide range of jobs in the architectural design process, thus it is important to comprehend both the benefits and drawbacks of this technology, particularly for those who are concerned about sustainability and the environment (Abd El-Maksoud & Ahmed, 2024). When constructing concentrate, AI takes into account factors like comfort, environmental preservation, reducing the adverse effects of climate change, and making use of data inputs like weather, temperature, humidity, etc. As a result, AI-generated designs can produce realistic, accurate, and suitable simulations that can be used to change plans and ideas, facilitate decision-making, and translate them into design principles (Abd El-Maksoud & Ahmed, 2024). Considering all these benefits, the current research literature recommends using AI to change traditional workflows, especially in the early stages of a project, to provide quick and attractive alternatives as a benefit to architects.

According to reports, the relationship between artificial intelligence and contemporary architectural styles has received a lot of attention in the architecture literature. The use of AI in climate change mitigation, biomimetic database management, and weather data management was examined in a study by Nour ElDin (2023). The study also emphasized the value of AI programmers in utilizing variables and inputs, developing algorithms, automatically updating databases, generating scenarios, making decisions, and cutting down on time.

AI in architecture has the potential to increase cost, time, and material efficiency. Furthermore, it contributes to the enhancement of designs and their progressive development. It also makes building safer and more sustainable. Artificial intelligence-generated graphics that explore traditional architectural styles by fusing them with more contemporary designs or utilizing traditional design aspects in more streamlined and futuristic ways Chang et al., 2023; Gajjar, 2023).

Numerous forms of artificial intelligence are employed in architecture, including computer-aided engineering design, automation in construction, and security and safety in buildings, according to Abd El-Maksoud and Ahmed (2024). But when it comes to incorporating AI in the design process, there are a lot of obstacles. Predictability, Compatibility with Current Technologies, Legal and Legislative Challenges, Investments, Data Quality, and Ensuring the Security and Privacy of Design and Construction Data are a few of these. These may inhibit the use of AI technologies in architecture on the one hand, and reduce the interest of architects in using AI. Taking into account all these, the current research is aimed at investigating the viewpoints of the architects on using AI in architectural design through a case study in Iran.

2. Statement of the Problem

The new science of artificial intelligence (AI) uses, analyzes, and modifies data to accomplish tasks and reach objectives. At the moment, artificial intelligence (AI) is dispersed throughout many disciplines and includes a large number of subfields, including modeling, anomaly detection, association, and grouping (Amer, 2023). Abd El-Maksoud and Ahmed (2024) point out that green architecture is the process of creating structures with concepts that protect the environment, and artificial intelligence (AI) offers countless design options and ways to implement the principles of green architecture. AI can assist in achieving the goals of green design since it also helps measure energy use in buildings for waste management, emissions reduction, sensor systems, data mining, heating, cooling, and lighting. Pena, Carballal, Rodríguez-Fernández, et al. (2021) emphasize that conceptual architectural design is a complicated process that uses creativity and prior experience to produce new designs. As the design requirements are still unclear in the conceptual stage, using AI in this process shouldn't be focused on finding a solution in a predetermined search space. Rather, this approach ought to be viewed as an investigation of the requirements and potential ways to satisfy them.

The other factor to take into account is that, in tandem with the growing discussions about AI and sustainable energy, the ethics of AI and its potential harm to society and the environment are currently being debated worldwide. To further the route toward sustainability, such as sustainable energy, sustainable AI is suggested in these arguments (Saheb, Dehghani, & Saheb, 2022). Accordingly, Debrah, Chan, and Darko (2022) contend that the architecture, engineering, and construction industry faces significant sustainability and efficiency issues and come to the conclusion that integrating AI into green building is a practical way to improve the industry's sustainability and efficiency. In light of this, they also draw the conclusion that although research has been done in the field of AI in GB, a thorough analysis of the current state of the field is required. In a similar vein, Meena, Kumar, et al. (2022) affirm that a critical evaluation of the current and previous research in the field of Green Building Technology (GBT) is lacking in order to determine the future course for sustainable green building technologies. The prospective uses of AI picture generators in architecture education are still not fully explored, despite the quick integration of AI tools across several fields (Fareed, Bou Nassif, & Nofal, 2024).

Furthermore, it has been confirmed by Shi, Seo, Cha, Xiao, and Chi (2024) that the current generative AI-based techniques for automated architectural exterior conceptual design are limited to using the general image description as a prompt. As a result, the generative image AI is unable to generate suitable design alternatives that satisfy a variety of design requirements. According to Yigitcanlar, Mehmood, and Corchado (2021), there is a greater need for a green AI method. However, Beyan and Rossy (2023) assert that the AI Image Generator alone is sufficient to generate a variety of viewpoints, even in the field of architecture. In face of these ambiguities, and the gap in the existing literature, especially analysis of use of AI in architecture, from the viewpoint of architects, the current research has been formulated to address the gaps, and to shed light on the ambiguities in the realm of architecture and applying AI tools and technologies.

3. Research Objectives

1) To determine the possibility of AI in supporting green architecture design

2) To determine the possibility of AI in achieving the principles of green architecture

3) To examine the architects' viewpoints regarding the role of AI in achieving the principles of green architecture by using a questionnaire

4) To determine the most common AI programs used by architects the most

4. Literature Review and Previous Studies

Abd El-Maksoud and Ahmed (2024) examined the idea of artificial intelligence, its function in architecture, and the most significant applications in order to determine its purpose and how it may be used to apply the principles of green architecture. Additionally, the study used a questionnaire to gauge the architects' perceptions of artificial intelligence's contribution to the realization of green architectural principles. The findings of the study showed

that, although it needs human support, artificial intelligence now holds the potential to completely transform the field of sustainable design. Additionally, it was determined that it is critical to comprehend the advantages of artificial intelligence and use it to implement green architectural principles.

In their questionnaire on art and machine learning, Kuo and Lee (2024) covered a wide range of topics, including whether AI systems can analyze large datasets and spot patterns, as well as how this skill affects the creation of fresh creative conceptions and ideas. Their study also included a number of recommendations and ideas that provided insight into the use of AI.

Cudzik, Nyka, and Szczepański (2024) investigated the necessity of modifications and adjustments in the design education process as AI-related technologies, which rely on picture generation, alter the creative process and present new possibilities. Students who used AI tools in a research-by-design studio at a Polish architecture university produced more inventive and ground-breaking designs than those created with conventional methods. These findings led to the identification of three different approaches to using AI tools. AI-generated graphics were only used as inspiration in the semi-traditional method. Students incorporated pieces of these photos into their own urban choices in the hybrid system. Lastly, students employed the higher-order loops in computer-human interaction to attain more site-specific outcomes in the hybrid-interactive approach. The research underscored the vast potential of AI integration, using image generation models in reshaping architectural design methodologies based on best practice.

Nofal, Fareed, and Bou Nassif (2024) investigated how AI image generators might be used to teach architectural history and sought to learn more about how using AI picture generators—particularly Leonardo AI's capabilities—could improve interaction and communication. They used an experimental approach to look into how incorporating AI picture generators into teaching about "History of Architecture" could improve the educational process by providing fresh viewpoints, interactive tools, and visualizations. To investigate the possible uses of AI picture generators in teaching architectural history, two workshops were held with university students. While the second session sought to evaluate students' analytical abilities, the first workshop used an iterative method. Determining the tool's capabilities and igniting debates about possible future applications were the ultimate goals. After the sessions, educators were interviewed and students were given online surveys to complete. The research's conclusions emphasized the necessity of certifying AI-generated images, creating policies to stop abuse, and creating specialized AI resources for architecture history classes.

An automated architectural exterior conceptual design approach was proposed by Shi, Seo, Cha, Xiao, et al. (2024) by integrating sketch-to-image synthesis and domain-specific prompting strategies into refined generative picture AI models. The suggested method incorporated general picture description annotations and textual design intent annotations to architectural photos. ChatGPT and a web crawler automatically retrieved annotations pertaining to design intent from internet sources for well-known architectural pieces that were utilized as training photos. The generated dataset was then utilized to train a generative AI model using the Lora algorithm, which taught the computer to comprehend the goal of textual design. In order to allow the generative AI to represent the design intent conveyed by the sketches, ControlNet was also utilized to regulate the SD model creation process. By contrasting the images produced by our method with those from two other models, the suggested method was verified. Based on the architectural design intent, the findings shown that the suggested method can effectively produce architectural external conceptual design images that meet the necessary specifications. It was anticipated that the suggested method would simplify and ease laborious and taxing iterative procedures in the conceptual design stage.

According to Manuel, Kehinde, Agupugo, and Manuel (2024), the use of AI in the renewable energy sector has transformed the effectiveness and use of renewable energy sources in modern construction, having a major influence on the operations of visual power plants. They highlight AI's revolutionary potential in renewable energy and its pivotal role in influencing the direction of sustainable building methods in the future. Additionally, they stated that AI makes it easier to design and create smart infrastructure and buildings, seamlessly integrating renewable energy systems. As previously stated, AI-driven energy management systems in buildings optimize energy use, monitor consumption trends, and encourage energy-saving behaviors, all of which increase total energy efficiency. They contend that such integration not only fits with international sustainability goals but also lowers the carbon impact of building projects.

Based on a thorough literature study and four potential levels—input, output, collaboration, and creativity—Vissers-Similon, Dounas, and De Walsche (2024) offered a strategic classification of AI techniques. When applied in the early phases of architectural design, their classification illustrated the possibilities and difficulties of the AI methodologies. In order to maximize the use of current computing power in architectural design workflows, they

sought to ascertain whether AI techniques would be worthwhile pursuing for particular jobs. According to the findings, the technologies with the biggest potential to influence early architectural design are evolutionary computing, transformer models, and graph machine learning. As such, they should be given the attention they need to realize their full potential. Additionally, the categorization helped create multi-method applications and determine which AI technique is best for various situations, such as the architect's programming abilities, the availability of training data, or the type of design problem.

Amer (2023) sought to inspire architects to begin using AI in a friendly manner and to make clear the benefits of incorporating it into architectural design. The researcher employed a two-pronged approach, showcasing relevant material and providing an overview of a few published case studies of applied and planned projects. It was determined that in future projects, AI will be used and significantly impact architecture practice.

Hegazy and Saleh (2023) conducted a study that examined the development of artificial intelligence's involvement in architectural design. It came to the conclusion that while AI has the potential to inspire and improve architectural design, its application must be morally and responsibly managed to prevent detrimental impacts on human creativity and design ethics.

In order to improve the design process, Ko, Ajibefun, and Yan (2023) presented a new architectural design framework that combines parametric modeling, Building Information Modeling (BIM), and generative AI tools like ChatGPT and Veras. Beyond its application in text and 2D image production, they investigated with ChatGPT's and generative AI's potential in 3D architecture design. It was asserted that the suggested framework will encourage architects and AI to work together, enabling rapid design concept exploration and generating innovative, context-sensitive design. The framework gives architects a simple and effective way to communicate design intent by combining ChatGPT for scripting and Veras for generating design ideas with popular parametric modeling and BIM technologies. This results in more effective, innovative, and cooperative design processes.

In their comprehensive literature review, Beyan and Rossy (2023) examined five books, twelve scientific publications, and five official websites. The findings clarified that by offering a number of design options with excellent visuals, the AI Image Generator might advance the process of developing creative ideas. Additionally, they stated that the difficulty is in the user's ability to provide written commands that AI systems can recognize. If this program is further developed, it has the potential to become a rendering tool that can eliminate the need for high-spec devices and other editing software.

According to Patil, Boraste, and Minde (2022), developments in green technology have made it possible to employ more ecologically friendly building materials. According to their analysis, the secret to successful green building initiatives is technology. They next go over a number of green building technologies, such as photovoltaic-powered cooling systems, wastewater treatment systems, energy efficiency, and temperature reduction.

Saheb, Dehghani, and Saheb (2022) presented a new contextual topic modeling approach that combines clustering, BERT, and LDA. To determine the primary scholarly topics, sub-themes, and cross-topic themes within scientific research on sustainable AI in energy, they integrated these computational analyses with content analysis of relevant scientific publications. Sustainable buildings, AI-based DSSs for urban water management, climate artificial intelligence, agriculture, the convergence of AI and IoT, AI-based assessment of renewable technologies, smart campus and engineering education, and AI-based optimization are among the eight main areas they identified. On the basis of the identified theoretical gaps, they then suggested possible lines of future investigation. They explored scientific books and identified problems and potential answers using a revolutionary topic modeling tool.

The synthesis between AI and green building (GB) was presented by Debrah, Chan, and Darko (2022), who also highlighted research trends and knowledge gaps that may be addressed in future studies on AI in GB. Based on 383 research papers found in Scopus, a quantitative bibliometric analysis was carried out to impartially determine the main research hotspots, trends, knowledge gaps, and future research needs. Additionally, 76 screened research publications on AI-in-GB were subjected to a qualitative systematic analysis. Knowledge gaps were found through this mixed-methods systematic review, and the following areas of future research on AI-in-GB were suggested: blockchain; digital twins and AI of things; robotics and 4D printing; and the moral, ethical, and legal obligations of AI-in-GB. By synthesizing the state-of-the-art of AI in GB and identifying research priorities in this area to improve the sustainability and efficiency of the AEC industry, their work contributed to the GB knowledge domain.

With the aid of appropriate study approach, Meena, Kumar, et al. (2022) discovered a critical review concerning Innovation in the Green Building Sector for Sustainable Future. After examining previous research on many topics, they identified several important challenges in green building research, such as the use of less natural resources, cost effectiveness, and lengthier design and construction times while taking future prospects into account. They also looked at the current status of green building construction and offered suggestions for additional research and

advancement that will be required for a sustainable future. Additionally, they noted a few potential avenues for future sustainable development study.

The study conducted by Pena, Carballal, Rodríguez-Fernández, Santos, and Romero (2021) examined significant research initiatives that include artificial intelligence solutions into the conceptual design of architecture. Although they looked at a number of methods, the majority of the research focused on using evolutionary computing to complete these objectives. They observe that the quantity of papers has significantly increased recently, particularly since 2015. Cellular automata and other evolutionary computing approaches are used by the majority. While the most recent study focuses on improving architectural form, the majority of early attempts were focused on discovering novel and creative forms. Additionally, they concluded that AI techniques play a significant role in solving conceptual design difficulties in architecture and that there has been a noticeable surge in artificial intelligence research since 2015 as it helps solve architectural design problems and produce more complex shapes.

Yigitcanlar, Mehmood, and Corchado (2021) focused on the "green AI" concept as a catalyst for the transformation of smart cities because it provides a way to shift from purely technologically oriented efficiency solutions to equitable, sustainable, and efficient solutions that can help achieve the intended urban futures. They made an effort to draw attention to the basic flaws in the conception and application of mainstream AI systems and to promote the necessity of a unified AI strategy, or "green AI," in order to further assist the transformation of smart cities. A comprehensive evaluation of the present literature, practices, advancements, trends, and applications related to AI and smart cities was part of the methodological approach. The findings helped planners and authorities understand the significance of implementing AI systems that tackle issues of equity, sustainability, and efficiency in urban areas.

Başarır (2021) offered a perspective on the main issues surrounding the incorporation of AI in architecture education. By the time students graduate, some of their hard skills and subject knowledge have gradually become inadequate or irrelevant. According to the study, including AI into the curriculum for architectural design helps designers become more knowledgeable about the input, process, and outcome of architectural design. The study examined the possibilities of incorporating AI applications and methodologies in architecture education, as well as how architectural design practice may profit from them, by viewing successive learning experiences as a continuum. As a result, it shed light on how architectural design education might change in light of AI's potential effects on the Architecture Engineering Construction (AEC) sector.

5. Methodology

5.1 Research Design

In this research a quantitative descriptive design was employed, which is typically used to systematically collect and analyze numerical data to describe or summarize a population or phenomenon (Fischer, Boone, & Neumann, 2023). Since, a questionnaire was used in this research to find out about the viewpoints of the architects in relation with the use of AI in architecture, this design suited the research objectives.

5.2 Research Setting, Population, and Sample, and Ethical Considerations

Kerman City was chosen for this study because of its distinctive fusion of modern and historical architectural styles, as well as its increasing interest in incorporating cutting-edge technologies like artificial intelligence into design procedures. With a population of about 560,000, Kerman, one of Iran's largest cities, is situated in the southeast of the country (GhorbaniParam, 2023 & 2024). The city is well known for its rich cultural legacy, which includes traditional Persian architecture. It is also the location of important historical sites like Rayen Castle and the Ganjali Khan Complex. Innovative designs that combine traditional and modern features have become more prevalent in Kerman's modern architecture (Minaei & Tajalli, 2009; Ilaghi Hosseini, Anjomshoa, & Abdollahi, 2017; Sobhani, 2023).

The population of this study included the architects in Kerman city, who were working in this field and had experience using AI throughout their works. To identify the sample, a purposive sampling method was used. Purposive sampling is a research technique that involves selecting participants intentionally to meet specific study objectives (Fischer, Boone, & Neumann, 2023). Since the inclusion criteria were (1) to work in the field actively, (2) to experience using AI, purposive sampling was used. Indeed, the study questionnaire was sent to the participants via different methods including emails, Telegram Accounts, or other social media websites, available to the participants. After all, around 51 questionnaires were returned and since some of them were incomplete, finally 46 questionnaires were considered for further statistical analyses.

All in all, although the research involved 46 architects working in Kerman, it is important to note that the total number of architects in the city is not precisely documented. However, the selected participants represent a

significant portion of the architectural community actively engaged in the city's development. Some of these architects also contribute to projects in other cities across Iran and occasionally collaborate internationally, reflecting a diverse range of experiences and perspectives. Regarding green architecture, Kerman has shown a growing concern for sustainable practices, influenced by its arid climate and the need for efficient resource management (Iranmanesh, 2011; Sobhani, 2023). Examples include the use of local materials like mud bricks in construction and the design of buildings that optimize natural ventilation and lighting. While there is no comprehensive public policy exclusively dedicated to green architecture, initiatives promoting sustainability are gradually being integrated into urban planning and development strategies (Fani Molki, 2017). This context underscores Kerman's relevance as a case study for exploring the intersection of artificial intelligence and architectural design.

In conducting the research, careful attention was paid to research ethics, particularly regarding the administration of questionnaires. As the study involved interactions with human participants, ethical precautions were taken to ensure their rights and dignity were respected. Before answering the questionnaire, participants were required to sign a free and informed consent form, which clearly outlined the purpose of the research, the voluntary nature of their participation, and the measures taken to ensure the confidentiality of their responses. This form provided participants with sufficient information about the study and their role in it, enabling them to make an informed decision about their involvement. In addition to obtaining consent, other ethical protocols were adhered to, such as ensuring anonymity in data reporting to protect participants' identities and offering them the opportunity to withdraw from the study at any time without any repercussions.

The demographic information of the participants are as follows. Of the 46 architects who agreed to participate in this study, 39.1% were males while 60.9% were females, as tabulated in Table 1. In terms of education, it was found that 19.6% held an associate degree in architecture, while the largest attained a score of 52.2% having a bachelor degree of architecture. Also, 21.7% had master's degree, and a small portion of 6.5% had PhD. Table 2 displays the education status of the participants. In terms of Years of Experience, three categories were identified, i.e. between 1-5 years, which attained a portion of 23.9% while the largest went for the ones working for 6-10 years, i.e. 60.9%. Besides, 15.2% had a work experience above 10 years, as shown in Table 3. The last demographic information was in relation with the participants' work sector, and it was found that 39.1% worked as an interior designer, followed by 28.3% working as the exterior designer. Another proportion of 26.1% had a field work, and finally a small amount of 6.5% had an academic job, as illustrated in Table 4. To summarize, the largest segment of the sample participating in this study were females, and the largest group in education held BA degrees and above, and the largest segment had a work experience between 6 and 10 years while the largest segment also worked as an interior designer.

Table 1. Participants' gender information

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	18	39.1	39.1	39.1
Female	28	60.9	60.9	100.0
Total	46	100.0	100.0	

Table 2. Participants' education status

	Frequency	Percent	Valid Percent	Cumulative Percent
Associate Degree	9	19.6	19.6	19.6
BA	24	52.2	52.2	71.7
Master	10	21.7	21.7	93.5
PhD	3	6.5	6.5	100.0
Total	46	100.0	100.0	

Table 3. Participants' work experience

	Frequency	Percent	Valid Percent	Cumulative Percent
1-5	11	23.9	23.9	23.9
6-10	28	60.9	60.9	84.8
Above 10	7	15.2	15.2	100.0
Total	46	100.0	100.0	

Table 4. Participants' work sector

	Frequency	Percent	Valid Percent	Cumulative Percent
Interior designer	18	39.1	39.1	39.1
Exterior designer	13	28.3	28.3	67.4
Field work	12	26.1	26.1	93.5
Academic	3	6.5	6.5	100.0
Total	46	100.0	100.0	

5.3 Research Instrument

In this study, a questionnaire used by Abd El-Maksoud and Ahmed (2024) was adopted, and then it was translated into Persian (back-to-back translation). Back-to-back translation is a method used in research to translate a questionnaire into a different language and then back into the original language to compare the two versions. After translating the questionnaire into Persian from the source language, which was English by one translator, a different translator, who was unaware of the original questionnaire, translated the target language version back into the source language. Finally, comparison was made between the original and back-translated version to identify potential errors in the translation. The questionnaire includes 18 questions measuring the extent of their knowledge of artificial intelligence and its capabilities in the design process, the expected obstacles facing artificial intelligence in architecture, and the role of artificial intelligence in generating appropriate solutions for the goals of green architecture. The questionnaire included different parts as follows:

- **Demographic information:** this section asked questions about four demographic information including the gender, education, years of experience, and work sector.
- **Section 1:** this part of the questionnaire included 15 questions with Yes/No/Maybe choices for the respondents. The questions are listed in Table 6.
- **Section 2:** it contained 3 questions, each having three choices to pick from, as in the following tables.

In order to determine the reliability of the questionnaire, a Cronbach's alpha was used, which is a way of assessing reliability by comparing the amount of shared variance, or covariance, among the items making up an instrument to the amount of overall variance. As shown in Table 5, the Alpha was 0.71, which means the questionnaire was reliable.

Table 5. Reliability statistics

Cronbach's Alpha	N of Items
0.710	18

6. Results and Findings

After transferring the data into SPSS Version 25, the data were analyzed through descriptive statistics for further interpretation. The findings related to Section 2 of the questionnaire have been provided in Table 6. The findings can be summarized as follows:

Table 6. Results of Section 1

Questions	Yes	No	Maybe
1. Have the buildings been designed with AI become more interactive and appropriate to the needs of users?	76.1%	15.2%	8.7%
2. Was the effect positive about the potential impact of AI on the design of green architecture?	87.0%	4.3%	8.7%
3. Is the AI, in the design stage, used in an appropriate way to the users' culture and the architectural identity?	4.3%	39.1%	56.5%
4. Did AI techniques give multiple alternatives to environmental treatments?	97.8%	-	2.2%
5. Will AI programs help the designer make design decisions to achieve the green architecture principles?	82.6%	10.9%	6.5%
6. Did the use of AI programs help site analysis and climatic data?	100%	-	-
7. Can AI programs comply with the green evaluation systems of LEED and BREEAM?	10.9%	28.3%	60.9%
8. Does AI affect energy saving?	93.5%	2.2%	4.3%
9. can artificial intelligence help save materials?	76.1%	15.2%	8.7%
10. Can AI help achieve thermal comfort in the building?	87.0%	4.3%	8.7%
11. Can AI help improve water efficiency?	60.9%	13.0%	26.1%
12. Does AI have a positive role in reducing carbon emissions?	41.3%	37.0%	21.7%
13. Can AI programs support innovative ideas and preserve intellectual property rights?	37.0%	30.4%	32.6%
14. Does education in the engineering sector need to develop its curricula to suite the era of AI?	100%	-	-
15. Do architects have the required experience to deal with AI programs?	52.2%	26.1%	21.7%

Majority of the participants confirmed that the buildings been designed with AI become more interactive and appropriate to the needs of users, i.e. 76.1%; in contrast, 15.2% chose No, while 8.7% chose maybe (Question 1). As for considering the positive effect of AI on the design of green architecture, interestingly, it was found that 87.0% of them responded yes, while a small portion of 4.3% and 8.7% mentioned No and Maybe, respectively (Question 2). Nonetheless, the respondents cast doubt on whether the AI, used in the design stage, can be in an appropriate way to the users' culture and the architectural identity. While only 4.3% chose Yes, the rest chose no and maybe, for 39.1% and 56.5%, respectively (Question 3).

As for Question 4, which focused on multiple alternatives given by AI techniques to environmental treatments, 97.8% agreed while only 2.2% showed hesitation. This means that the respondents in this study assumed that AI techniques could be of great assistance in providing alternatives to environmental treatments. As for question 5, i.e. AI programs help the designer make design decisions to achieve the green architecture principles, again, majority said yes, i.e. 82.6%, followed by a 10.9% disagreement and 6.5% chose maybe. This implies that the architects think AI is of importance in fulfilling green architecture principles. Another proof to this claim is that all the participants (100%) reported that the use of AI programs help site analysis and climatic data (Question 6). Nonetheless, when asked whether AI programs comply with the green evaluation systems of LEED and BREEAM (Question 7), only 10.9% agreed, while a third of the respondents chose NO, and two third said maybe, i.e. 28.3% and 60.9%, respectively. Another question about principles of green architecture asked about the effect of AI on energy saving, which received a high score of agreement (93.5%), which was similar to the effect of AI on saving materials (76.1%) as for questions 8 and 9. Other factors related to green architecture principle attained high scores of agreement respectively for thermal comfort (87.0%), water efficiency (60.9%), and reducing carbon emissions (41.3%), although the latter was below a half among the respondents. Yet, the results in this category are congruent with the participants' responses to question 5, that focused on green architecture.

Another interesting finding was that 37.0% of the participants agreed that AI programs support innovative ideas and preserve intellectual property rights while 30.4% disagreed and 32.6% chose maybe. Another interesting

finding was that all the participants agreed that education in the engineering sector need to develop its curricula to suite the era of AI, and above half confirmed that architects have the required experience to deal with AI programs.

To better understand the possibility of AI to make support Design green architecture, which could be measured through questions 4, 5, and 7, it was found, as detailed in Figure 1 that overall, it seems that there is a possibility of AI to support green architecture design because majority confirm that AI can give multiple alternatives to environmental treatments and can help the designer make design decisions to achieve the green architecture principles, although there is considerable doubt about AI programs compliance with green evaluation systems.

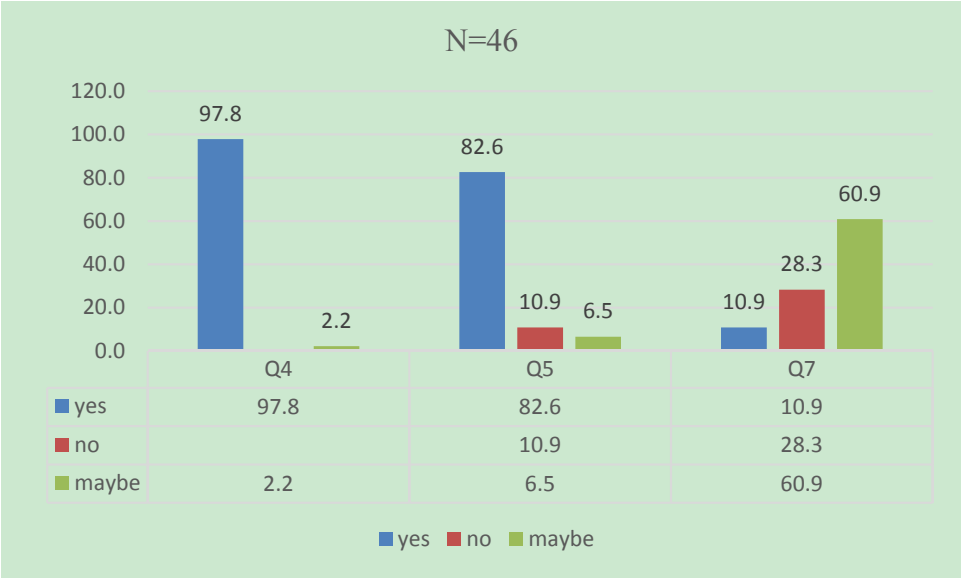

Figure 1. Possibility of AI to make support design green architecture

Besides, to determine the possibility of artificial intelligence to achieve the principles of green architecture, which was assessed via questions 6, 8, 9, 10, 11, and 12, overall, it can be concluded that in all the considered items, majority of the architects participating in this research confirmed that AI can achieve principles of green architecture, detailed in Figure 2.

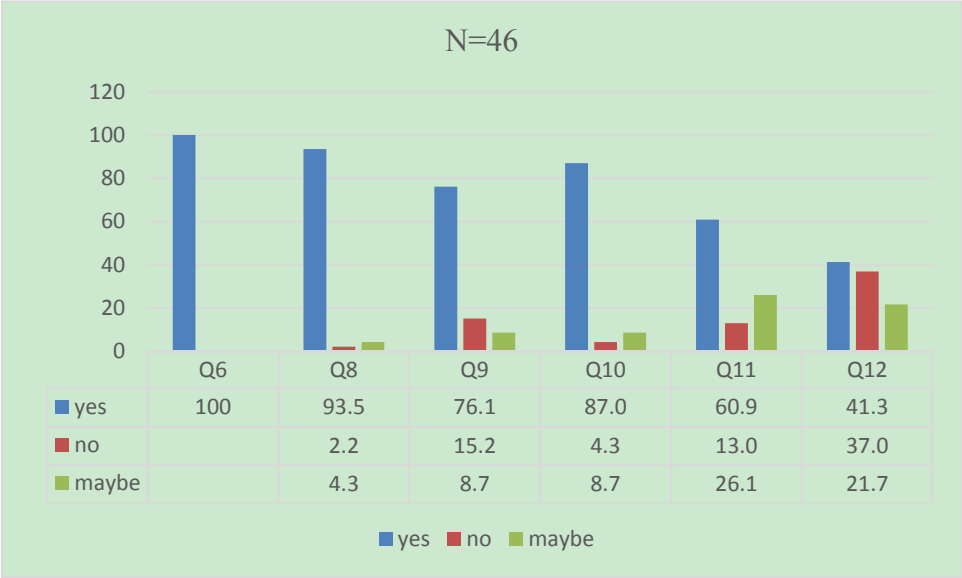

Figure 2. Possibility of artificial intelligence to achieve the principles of green architecture

The results and findings related to Section 2 of the questionnaire are as follows, which include three questions. When asked about the kind of projects that AI can help in the design process, more than half selected interior

design (52.2%), followed by Exterior Design with a rate of 39.1%. A small fragment also chose Infrastructure (8.7%). Therefore, AI was chosen to be helpful in interior design rather than the others, as illustrated in Table 7. Furthermore, the most common ways to use AI in architecture were found to be generating design with a rate of 63%, and Virtual Reality for 19.6% while operation and maintenance of the building ranked last with a score of 17.4% (Table 8).

Table 7. Kind of projects that AI can help in the design process

	Frequency	Percent	Valid Percent	Cumulative Percent
Exterior Design	18	39.1	39.1	39.1
Interior Design	24	52.2	52.2	91.3
Infrastructure	4	8.7	8.7	100.0
Total	46	100.0	100.0	

Table 8. The most common ways to use AI in architecture

	Frequency	Percent	Valid Percent	Cumulative Percent
Generate Design	29	63.0	63.0	63.0
Virtual Reality	9	19.6	19.6	82.6
Operation & Maintenance	8	17.4	17.4	100.0
Total	46	100.0	100.0	

Last but not least, the architects who participated in this study were asked if their experience of using AI in architecture was successful or not, majority of them mentioned that it was successful (78.3%), while 8.7% did not gain success and 13 % chose Unspecified, which means they were hesitant. To conclude, the experience of the architects participating in this study show that using AI through architectural phases could be successful, and that they have a positive viewpoint about using AI, as in Table 9.

Table 9. Participants' quality of using AI

	Frequency	Percent	Valid Percent	Cumulative Percent
Unspecified	6	13.0	13.0	13.0
Successful	36	78.3	78.3	91.3
Unsuccessful	4	8.7	8.7	100.0
Total	46	100.0	100.0	

Finally, the participants were asked to refer to the AI programs they most often use, the largest part chose Midjourny, 34.8%, and Veras 21.7%. The other programs were ARCHITEChTURES, with a rate of 19.6%, Arkdesign.ai with a rate of 10.9%, as well as AiMaket and Finch3D, both with the rate of 6.5. Table 10 and Figure 3 display the detail information about this finding.

Table 10. Participants' typical programs of use

	Frequency	Percent	Valid Percent	Cumulative Percent
AiMaket	3	6.5	6.5	6.5
Veras	10	21.7	21.7	28.3
Arkdesign.ai	5	10.9	10.9	39.1
ARCHITEChTURES	9	19.6	19.6	58.7
Midjourny	16	34.8	34.8	93.5
Finch3D	3	6.5	6.5	100.0
Total	46	100.0	100.0	

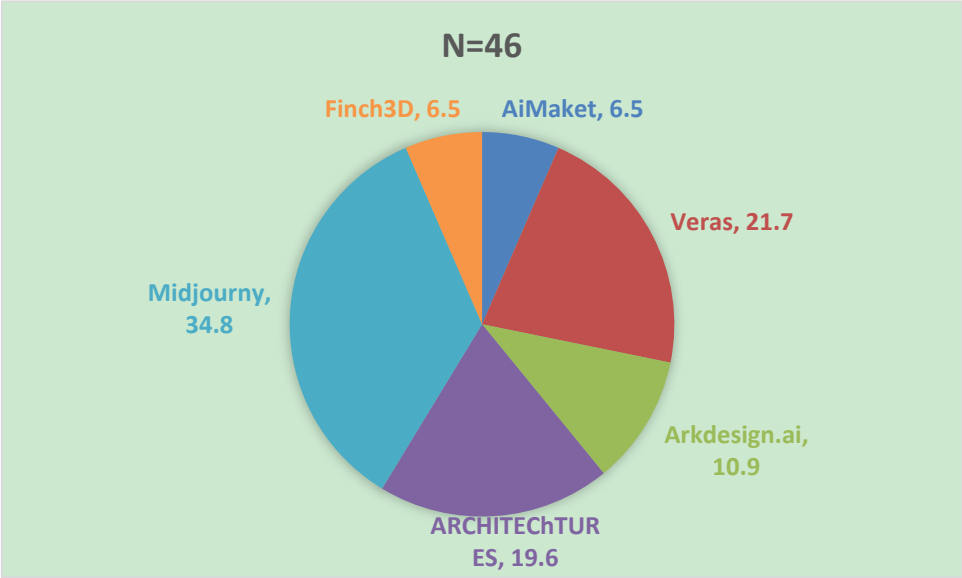

Figure 3. AI programs used frequently

7. Conclusion and Discussion

First of all, it was found that majority of the participants confirmed that the buildings been designed with AI become more interactive and appropriate to the needs of users. Also, majority of the participants confirmed the positive effect of AI on the design of green architecture. Nonetheless, the respondents cast doubt on whether the AI, used in the design stage, can be in an appropriate way to the users' culture and the architectural identity. In addition, most of the participants highlighted that AI techniques provide multiple alternatives to environmental treatments and majority confirmed that AI programs help the designer make design decisions to achieve the green architecture principles, which implies AI is of importance in fulfilling green architecture principles.

All of the participants reported that the use of AI programs can help in site analysis and climatic data but most of the respondents mentioned that AI programs do not comply with the green evaluation systems. Besides, majority of the respondents confirmed that AI can help in energy saving, thermal comfort, water efficiency, and reducing carbon emissions. Also, the participants agreed that AI programs support innovative ideas and preserve intellectual property rights although the rate was not very considerable. Moreover, all the participants agreed that education in the engineering sector need to develop its curricula to suite the era of AI, and above half confirmed that architects have the required experience to deal with AI programs.

Overall, there is a possibility of AI to support green architecture design because majority confirm that AI can give multiple alternatives to environmental treatments and can help the designer make design decisions to achieve the green architecture principles, although there is considerable doubt about AI programs compliance with green evaluation systems. To conclude, it was found that AI can achieve principles of green architecture. In line with this, it was found that AI can help in the design process, respectively in interior design, Exterior Design, and Infrastructure. Therefore, AI was chosen to be helpful in interior design rather than the others. Furthermore, the

most common ways to use AI in architecture were found to be generating design, Virtual Reality and finally operation and maintenance of the building with the lowest rank.

Majority of the architects who participated in this study mentioned that their experience of using AI in architecture was successful. Finally, the most common AI programs sued most often use were respectively Midjourny, Veras, ARCHITEChTURES, Arkdesign.ai as well as AiMaket and Finch3D.

8. Research Limitations

The first limitation of this study is related to its scope. Since this study was a case study in the city of Kerman, Iran, the findings are based on architects' perspectives in Kerman, which may not fully represent opinions in other cities of Iran or even other countries. Besides, the sample size could be another limitation as only 46 architects participated in this case study and it is acknowledged that this sample size might affect the generalizability of the results. Last but not least, there is limitation from technological point of view, i.e. rapid advancements in AI could lead to different outcomes in the future.

9. Future Research Directions

Primarily, expanding the study area is recommended and replicating the research in other regions or cultural contexts to see if the findings hold nationally, or universally would be suggested. Moreover, further research is proposed into newer AI technologies and their potential for achieving green architecture. In terms of methodology, other research studies can be implemented by combining quantitative and qualitative approaches as a mix of methods (e.g., interviews with architects or case studies of projects) for deeper insights. Finally, exploring the long-term sustainability and environmental impact of AI-driven designs in real-world applications is recommended to assess long-term impact:

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Authors contributions

Ms. Ayda Gharaei led the study conception and design, oversaw the data analysis, and drafted the manuscript. She also coordinated communication with collaborators and served as the corresponding author. Ms. Elnaz Shirvanisaadatabadi conducted the experimental procedures and data collection and she also contributed to data interpretation and provided critical revisions to the manuscript. Ms. Sima Salahshour performed the statistical

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Data sharing statement

No additional data are available.