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Impact of AI on Architecture: An Exploratory Thematic Analysis

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Abstract

The huge impact of artificial intelligence (AI) on various spheres is commonly attested in the literature. This study is informed by the dire need for more research on, increased adoption of, and awareness about AI for architectural activities. It is aimed at exploring the impact of AI on architecture, with a view to drawing evidence from extant studies to determine the extent of its adoption and positive impact on architecture. To show scholarly evidence for its arguments on the thematic concern, literature review process, interpretive devices, and content and thematic analyses are employed. Being an exploratory research, exploratory method and qualitative approach are employed. The study relies on observation and secondary data, focusing on their thematic preoccupations in relation to its arguments. The data are sourced online from only reputable repositories and databases. The analysis demonstrates that AI has been impacting positively on the broad field of architecture, and has the capacity to optimize and transform the architecture industry with huge innovations, results, efficiency, performance, and productivity. The study concludes that AI and other cutting-edge technologies, as technological innovations, are transforming the broad field of architecture. It charges government and stakeholders in the field to ensure significant adoption of AI and increase awareness about AI, its impact, and ethical concerns. Ethical governance and pragmatic measures can help address the ethical concerns associated with AI.

Keywords: AI, Technologies, Impact, Architecture, Optimization, Transformation.

Introduction

The impact of artificial intelligence on various facets of life is affirmed by many recent studies (Kodete et al., 2024; Otasowie et al., 2024; Pasupuleti et al., 2024; Thuraka et al., 2024). Some others are Akinola (2024), Akinola et al. (2024), Nwadinobi et al. (2024), Nwosu et al. (2024), Obiuto et al. (2024), Okusi (2024a&b), Oyeyemi et al. (2024), Juhrich (2023), Ivanova et al. (2023), Regona et al. (2023 & 2022), Kochovski and Stankovski (2021), Artificial Intelligence Bangladesh (2020), Wang (2019 & 2012), Pim-Wusu et al. (2024), and Yigitcanlar et al. (2020). While the different studies focused on one integral part of a broad field, this present study engages specifically with the impact of AI on the broad field of

architecture in recent times. AI is traced to John McCarthy in 1956, who coined the concept to describe machine logic that derives from human brain (Lukovich, 2023; Chaillou, 2019). Oliver Selfridge is noted to be the one who came up with the idea of the non-human based AI in the 1960s, being autonomous software agents capable of performing tasks undertaken by human beings (Lukovich, 2023; Hoar et al., 2017).

Today, AI has come to stay in the 21st century digital world of globalization. Its impact on various endeavors is unanimously attested. Its adoption level varies among organizations and nations. In the same vein, while some fields have gained significant scholarly exploration of AI, others are yet to. This study is an attempt in that direction to increase awareness about AI in the field of architecture, affecting change in several regards therein. This is possible in that by appraising the valuable impact of AI on architecture, many individuals, organizations and nations would see the dire need to adopt AI significantly for various architectural activities, while others would take up further research on AI in architecture. The foregoing points underline the novelty of this study.

Statement of Problem

The architecture industry is yet to significantly migrate from conventional means of operations to technology-driven means. As Marsh (2020) observes, the current state or level of integration of AI and other cutting-edge technologies into the architecture industry is insignificant. The present study adds that the integration of AI into the architecture sector is yet to reach appreciable state or extent. The backdrop has possible traces to the attendant issues of AI adoption and usage. These include cyber threats and crimes, AI safety and fairness, violations of ethics and human rights, data security threats, privacy invasion, technological unemployment, etc. (Okusi, 2024a&b; Marsh, 2020; Yigit et al., 2018). AI needs voluminous data for high results and so its prime limitation is data (Cudzik & Radziszewskí, 2018). The reason is that the more the data, the better the results (Lukovich, 2023). Financial challenges to the adoption of AI are also affirmed in the literature (Akinola, 2024; Akinola et al., 2024; Okusi, 2024a).

The need to affect a change to that end is what gave rise to this study. The essence is to contribute to increasing the adoption of AI by a larger number of organizations for architectural undertakings. Also, by appraising the impact of AI on architecture, individuals, organizations and governments would see the need to increase the adoption of AI for architectural activities and make concerted efforts to ameliorate the challenges of AI adoption, for which some organizations and governments have not significantly adopted AI for architectural purposes.

Aim and Objectives

The aim of this study is to explore the impact of artificial intelligence (AI) on architecture. The specific objectives are to:

i. Assess the impact of AI on the architecture industry.

ii. Ascertain the extent to which AI has impacted positively on architecture.
iii. Determine the extent to which AI is currently integrated into architecture.
iv. Show evidence from extant studies that AI is capable of addressing many of the challenges of the architecture industry.

Research Questions

The following research questions are designed to guide the study:

i. What impact has AI on the architecture industry?
ii. To what extent has AI been impacting positively on architecture?
iii. What is current extent of AI integration into architecture?
iv. Show evidence from extant studies that AI is capable of addressing many of the challenges of the architecture industry

Scope

The study focuses on demonstrating the impact of AI on architecture. Its scope concerns are:

- Highlighting the impacts of AI on architecture.
- Showing how AI has been impacting on architecture.
- Determining the extent to which AI impacts on architecture.
- Ascertaining the current extent of AI integration into architecture.
- Contributing to the growing volume of literatures on AI.
- Drawing evidence from extant literatures to justify the claim that AI has been impacting on architecture and ought to be used more significantly to increase the impact and optimize the architecture industry.
- Identifying the matters arising from AI usage.
- Suggesting ways of addressing the rising issues of AI adoption and usage.

Theoretical Framework

The study is anchored on the Unified Theory of Acceptance and Use of Technology (UTAUT), propounded by Venkatesh et al. (2003). UTAUT explains technology acceptance and use. It combines the postulations, ideals and aspects of eight other theories of computation, information, technology and communication sciences, and innovation adoption. These are Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), Motivational Model (MM), the combined TAM and TPB (C-TAM-TPB), the Model of PC Utilization (MPCU), the Diffusion of Innovations Theory (DOI), and the Social Cognitive Theory (SCT). The implication is that UTAUT is integrative and comprehensive. It has four pillars or constructs viz:

i. **Performance Expectancy:** This aspect of UTAUT refers to the extent to which an individual believes that using technology would help them to perform better.

ii. **Effort Expectancy:** This refers to the expected efforts as well as the expectations grounding the efforts being made to adopt technology and use it accordingly. That is, technology is being adopted for given purposes. These constitute the expectations, for which efforts are made to realize them.
iii. **Social Influence:** Since technology or any innovation obtains in a social setting, social influence impacts on technology adoption. The idea is that the extent to which a given technology is perceived by other individuals to be relevant determines some other individuals' perception, interest in, or attitude towards the technology. In that case, social influence comes from the other individuals to the individuals adopting the technology.
iv. **Facilitating Conditions:** There certain conditions that enable the adoption of a technology, while others do not. Such conditions determine or influence the extent to which individuals believe that organizational and technical infrastructure exists to support the use of the technology.

Obviously, the above four cardinal points of UTAUT aptly describe what directly influence technology acceptance and usage behavior among individuals. They (the four constructs) are moderated by individual characteristics such as experience, gender, age, and voluntariness of use. As the proponents of UTAUT model modified it further, they added other constructs such as hedonic motivation, price value, and habit as what explain as well as determine or influence technology acceptance and use. Given the foregoing, it is quite clear that UTAUT is a suitable theoretical framework to this study.

Related Studies

Lukovich (2023) explores AI in architecture, stressing that deploying AI for the attainment of technological innovations in the architecture industry is a new paradigm. The study makes it clear that the application of AI is no longer specific to any science field. Rather, all spheres are keying and should key into it. The application of AI in the field of architecture implies its application in fine arts, technology and science respectively and in combination. The study expresses hope for appreciable integration of AI into the field of architecture in the nearest future. It emphasizes that AI holds a lot of prospects (new opportunities) in stock for the industry. According to the study, attitudinal change influences the decision on whether to adopt it or not.

Also, the study expresses concern about the consequences AI has for architects in the future. For the present study, whatever consequences can be mitigated by architects, once there is the willingness to do so. It agrees with the Lukovich's (2023) study that changes brought forth by AI in design architecture should be assessed and more awareness created. By so doing, the feared consequences can be mitigated, as architects become more aware and willing to use AI, ensure best practices, and look out for solutions to the consequences. The present study does not focus on the impact of AI on creative design architecture alone, but architecture as a whole. It advocates wide adoption of AI across the whole field of

architecture so as to increase its impact on the sector. The following images presented by Lukovich's (2023) study are of symbolic relevance to this present study:

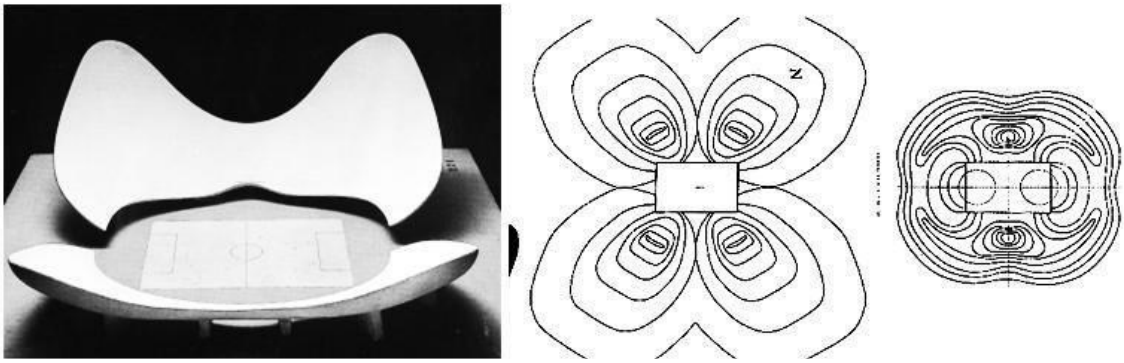

Fig. 1: The 'surprising' shape: Moretti's pioneering theoretical stadium design

Fig. 2: The curving surface of the iconic Guggenheim Museum in Bilbao (Frank O. Gehry)

Fig. 3: The sculptural Yokohama Terminal in Japan (FOA Group) & Fig. 4: Two 'etalon buildings': the Copenhagen (Henning Larsen) and the Tenerife (Santiago Calatrava) Opera houses

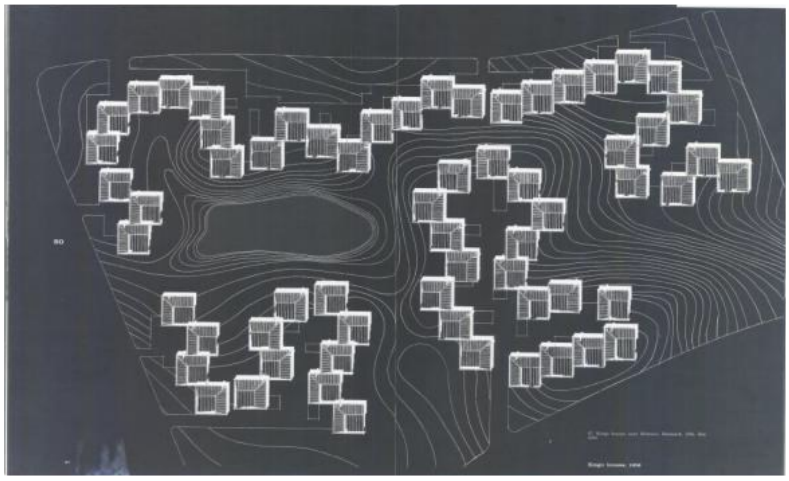

Fig. 5: 'Repetitive' housing project (Utzon's Kingo Houses, Denmark)

Furthermore, Pena et al. (2021) discuss AI in conceptual architectural design. Their study indicates that this kind of design is a complex one that relies on past experience and creativity to generate new innovative designs. It advocates the integration of AI into the generation of the new designs so as to produce technology-driven. The study advocates the integration of AI into the conceptual creation of designs in ways that can help professionals meet the requirements of these architectural designs. It points out that the application of AI in these designs helps optimize and revolutionize the activities involved. The study reveals that since 2015, there has been an appreciable increase in the numbers of scholarly papers on AI and evolutionary computing techniques. One of the prominent techniques is cellular automata. The study recommends the optimization of architectural activities using the cutting-edge technologies. The present study keys into its views and goes further to appraise the impact of AI on architecture in general, not only conceptual architectural design.

Chaillou (2019) shows that cutting-edge technologies have been impacting and proffering solutions to architectural design in four distinctive phases: modularity, computational design, parametricism, and artificial intelligence. These, according to the study, are overlapping and interdependent. The view aptly reflects the thematic concerns of the present study. Nevertheless, the present study looks at the overall impact of AI on architecture as a whole. Interestingly, the study affirms the impact of AI alongside other cutting-edge technologies on the field of architecture.

AI in Architecture

AI has significant presence in architecture. It has been impacting significantly on Architecture. The impact of AI on architecture cannot be overemphasized. To start with, the study avers that AI can be, and has been, used realistically in the broad field of architecture as well as in its subfields for various optimized purposes. In other words, AI has been used variously for architectural undertakings. Nonetheless, some of the undertakings

of architecture are yet to benefit from (significant) use of AI for their optimization, transformation, advancement, efficiency and productivity. The foregoing stance is in response to studies, such as Mungoli (2023) and Ro (2018), which state that AI technologies can be used in areas such as healthcare, education, agriculture, and societal issues. This implies that AI technologies also have applicability in architecture with the attendant impact.

Since a large number of extant studies engage with and stress the impact of AI on such broad fields alone, leaving out the case of architecture, there is the necessity for this study and the like others. This study argues that the field of architecture has been benefiting hugely from the cutting-edge technologies, among which are AI and smart technologies. The sector is getting transformed rapidly by these technologies. Design and construction processes are being reshaped, repositioned, redefined, optimized and transformed wholesomely by the technologies. The use of these technologies for architectural activities have also brought to place efficiency, increased performance, productivity and innovative building practices that promote the green environment movement (Akinola, 2024; Akinola et al., 2024; Okusi, 2024b; Otasowie et al., 2024).

According to National Strategy for Artificial Intelligence Bangladesh (2020), AI exhibits the capacity of machines to perform psychological errands like reasoning, seeing, learning, critical thinking and basic leadership. This point highlights the varied functions of AI in different contexts. From the foregoing, it is quite clear that AI has been exerting significant positive impact on various sectors, as affirmed by studies in different fields. Given the fact that AI exhibits a range of capabilities, it is quite obvious that it has the capacities to handle tasks undertaken by humans in the field of architecture. The diagram below symbolically summarizes the wholesome impact of AI on the field of architecture. In other words, this study avers that AI has been impacting on architecture as illustrated in the following diagram:

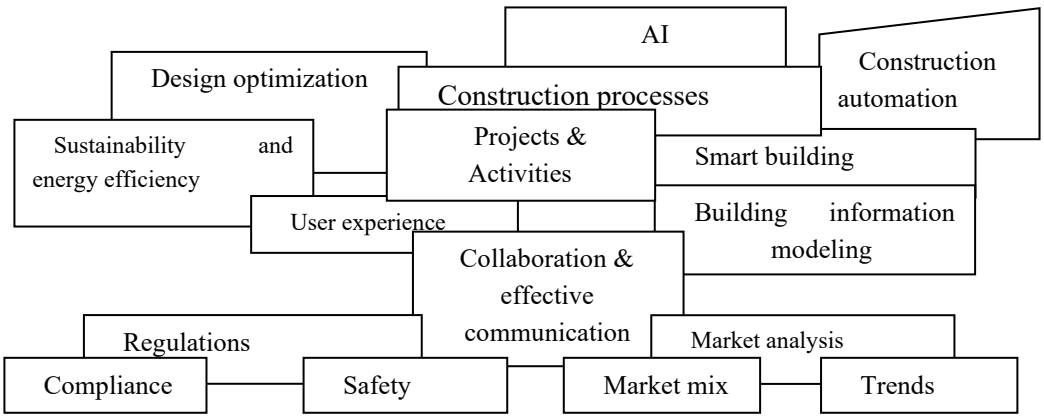

Fig. 6: Areas of AI impact on Architecture
Source: Authors, 2024

AI Impact on Architecture

The impact of AI on architecture obtains in different spheres of architecture. As different AI technologies play crucial functions in various spheres of life, they (can) do same in the field of architecture. Among the diverse functions of AI, through which it is has been impacting positively on architecture are the following:

- Prediction, detection, and mitigation of conventional and cyber risks (Adelani et al., 2024; Adewusi et al., 2024; Govea et al., 2024; Ojo & Aghaunor, 2024; Ojo et al., 2024; Thapaliya & Bokani, 2024; Yu, 2024)
- Optimization, automation and efficiency (Peramo et al., 2024; Volk, 2024; Chaillou, 2019)
- Maintenance, protection, organizing, and capacity building (Binhammad et al., 2024; Kalnawat et al., 2024; Peramo et al., 2024)
- Sustainability,
- Saving time and resources (Adewusi et al., 2024)
- Providing large data for different purposes (Thapaliya & Bokani, 2024; Lukovich, 2023; Cudzik and Radziszewskí, 2018)

Studies indicate that major AI algorithms commonly applied in the field of architecture are evolutionary/genetic algorithms, swarm intelligence, and neural networks (Lukovich, 2023; del Campo et al, 2020; Chaillou, 2019; Cudzik & Radziszewskí, 2018). The varied AI approaches are noted to be of two broad categories viz:

- The subsymbolic systems, which are the selected parameters usually analyzed in a hierarchical way; and
- The symbolic systems, which are autonomous processes operating in a non-hierarchical way, whereby the solutions are less expected (Cudzik & Radziszewski, 2018).

Studies show that AI has transformed, repositioned, optimized and automated architecture in different areas. These include urban planning and designs (e.g. Grasshopper, ANSYS CFX, and CityEngine), environmental sustainability, improved experiences in hospitality, professionalism, career development and growth, onsite and offsite constructions (Lukovich, 2023; Marsh, 2020; Cudzik & Radziszewskí, 2018; Taleb & Musleh, 2014; Schneider, Koltsova & Schmittt, 2011). Undoubtedly, AI has been impacting positively on both onsite and offsite constructions and other architectural activities. The impact is realized through the application of different AI algorithms in construction and architectural activities of various kinds.

They are deployed for optimization, designing, efficiency, quality, control, planning, monitoring, transformation, streamlining chain management, and execution of tasks and projects. These can be realized with machine learning, computer vision, robotics, Natural Language Processing (NLP), digital twins and real-time analytics, pattern recognition, and Internet of Things (IoT), among others. These are represented graphically by this study viz:

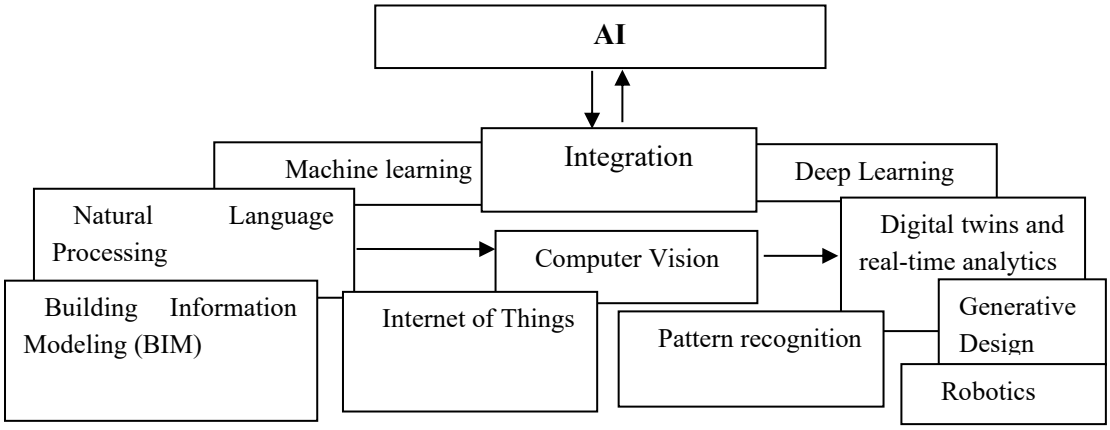

Fig. 7: Major AI Technologies Making Wave in Architecture
Source: Authors, 2024

Accordingly, different layout components are optimized by ML. It also help predicts and prevents project delays, and manages resources and time effectively. With big data, AI impacts on both onsite and offsite constructions, improves work processes, facilitates better decision-making, and proffers problem-solving capabilities. More so, robots are used to assemble construction components such as walls, plumbing, HVAC, and electrical systems, which are ordinarily handled by humans. Those equipped with cameras can monitor the progress of construction and identify risks, thereby ensuring effective management and assurance. Through sensors, drones, and other technologies, AI help provides valuable insights for maintenance and safety. Interactions among workers, machines and objects are monitored by smart wearable, such as helmets and vets (Umoh et al., 2024; Schwab, 2016). These are also ways through which AI has been impacting and can impact on architecture in various regards.

Construction documents and communications are automated by Natural Language Processing (NLP) algorithms. The automation helps to reduce the time spent on administrative tasks. Thus, projects are done expediently. Effective maintenance through prediction is done with AI algorithms like decision trees and support vector machines (SVM) (Akinola, 2024; Okusi, 2024a). With these, potential equipment failures are detected and prevented. AI helps with generative design that proffers innovations. With AI-powered generative designs, design process is enhanced significantly. Also, the impact of AI on the architecture industry accounts for why some organizations in the industry have been spending hugely on robotics, 3D printing, modularization, digital twin technology, analytics, and supply chain optimization.

The impact of AI on architecture obtains in the provision of virtual representation by digital twins and real-time analytics, which allow for remote management of construction. These AI technologies make it possible for project managers to plan, design and manage buildings and infrastructure more effectively. Also, AI applications in the field of architecture have been transforming bricklaying and painting. Apart from risk detection by machine learning,

deep learning and robotics (Okusi, 2024a), they optimize and improve decision-making and scheduling (Thuraka et al., 2024; Ogirri, 2024a&b). Aerial drones, which are some of the AI algorithms, are deployed for site surveys and the collection of data to generate 3D models of buildings. The AI subfield called pattern recognition involves data and system integration applications. These enhance safety management. When combined with data integration, virtual reality ensures personnel safety, and improves planning, inspection processes, training and AI user education.

As AI technologies are being integrated into architecture, the sector gets optimized, transformed, more data-driven, efficient, quality and safety-assured. These are made possible by machine learning (ML) algorithms used for predictions and other analytics (Okusi, 2024b; Wusu et al., 2022). Such ML techniques include logistic regression, decision tree, random forest, and AdaBoost (Akionla, 2024; Okusi, 2024a; Ivanova et al., 2023). Deep learning (DL) algorithms are used extensively for architectural design and visualization, including 2D and 3D generative applications (Okusi, 2024b; Thuraka et al., 2024; Baduge et al., 2022; del Campo et al., 2020; Mérő, 2019; PWC, 2019). Mean shift is an AI technology for locating the maxima of a density function, which is valuable for optimization and analysis of construction site data (Xu et al., 2021). No doubt, this is one of the AI technologies impacting significantly on architecture.

K-means Clustering is being employed for grouping similar data points, which can be used in managing and optimizing construction processes and materials (Xu et al., 2021). Faster R-CNN, computer vision algorithm applications, is deployed for identifying and tracking construction progress and elements (Alsakka et al., 2023). Canny Edge Detector is also applied in computer vision to detect edges in images that are valuable for identifying defects and other construction elements (Alsakka et al., 2023). Mask R-CNN is deployed for the segmentation of images that help in the identification specific objects within construction images, such as materials or structural components (Alsakka et al., 2023)

Obviously, drawing from the above, it is quite factual that AI has been impacting on architecture as a whole, even though the integration of AI is yet to reach a significant or appreciable level. That is why this study concerns itself with a critical exposition of how AI impacts on architecture and the extent of the integration of AI into architecture so far. It targets is to influence policies and regulations on AI in architecture and affect changes in the field.

Conclusion

The numerous prospects of AI obtain in the field of architecture. They constitute the positive impact of AI on architecture. The impact of AI on architecture is quite glaring. AI has been revolutionizing the architecture sector in various regards. Its impact includes efficiency, innovations, safety, automation, easy work processes, better scheduling, speediness in undertaking tasks, reduction of costs, time and resources, etc. An appraisal of the impact of AI on architecture is important so as to determine the current state-of-art

in the field, weigh or show the extent of the impact, highlight ways in which AI has been impacting on the sector, and showing evidence from extant literatures that AI has the capacity to cause more changes now and in the future in the sector.

Rather than focusing on the impact of some AI technologies on certain aspects of architecture, as done by previous studies, this study has taken a different dimension. It looks at the impact generically. It appraises the impact of AI in generic term on architecture as a whole. It has succeeded in demonstrating that just as AI has been impacting positively on various other endeavors, it has been doing same to the architecture industry, even though its integration into the sector is current insignificant. Regardless of the backdrop, the study expresses hope for future feats in the industry, which will be brought to place by AI. As the study calls for increased adoption of AI in the field of architecture, it contributes to raising awareness about AI in the field and beyond. The advocacy would lead to innovations, changes, and betterment.

Recommendations

Given the analytic and descriptive exposition, the study:

- Calls on stakeholders to make concerted efforts toward ameliorating the challenges of adoption and devise more efficacious technological and conventional measures for mitigating the attendant issues of AI.
- Charges stakeholders in architecture industry and the political realm to leave up to expectations in the adoption of AI and in addressing the associated issues and constraints to AI adoption so as to increase the adoption and usage of AI in the industry.

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