Afropolitan Journals

ISSN: 3027-2882 www.afropolitanjournals.com

Leveraging Cost-Effective AI and Smart Technologies for Rapid Infrastructural Development in USA

Akintayo Philips Akinola

2050 Sustainability Dr, DFW Airport, TX 75261.

Corresponding author: akintayo.p.akinola@gmail.com

DOI: *https://doi.org/10.62154/rktd4f30*

Abstract

High cost of building makes houses expensive for US citizens and residents. Thus, this study proposes the leveraging of cost-effective artificial intelligence (AI) and smart technologies (ST) for rapid infrastructural development in US. It considers them as sustainable means of tackling the challenges for the attainment of affordable houses. The study explores the potentials of prominent AI and smart technologies capable of reducing the cost of building houses in the US, for which houses would become affordable for all. The primary data are obtained from telephone interviews with 10 construction workers and 5 experts of AI, alongside observation and introspection. The secondary data are drawn from library and the internet. Qualitative method, thematic and content analyses, systematic review, and descriptive and interpretive tools are employed. The results show Machine Learning, Natural Language Processing, Computer Vision, Reinforcement Learning, and Robotic Process Automation to be prominent cost-effective AI technologies, while Building Automation Systems, Internet of Things, Renewable Energy Systems, and Smart Water Management Systems are cost-effective smart technologies. The study concludes that the identified AI and smart technologies are not only cost-effective, but also transformative and innovation-driven and can be leveraged to increase efficiency, productivity, quality delivery and satisfactory services. The study recommends them to government and organizations for cost-effectiveness towards attaining rapid infrastructural development in the USA.

Keywords: Leverage, Cost-Effectiveness, AI, Smart Technologies, Infrastructural Development.

Introduction

High cost of building makes houses expensive for US citizens and residents. The rising cost of houses and building projects in the US is worrisome, though no deserving scholarly attention has been paid to it. A critical reflection on the potentials of the contemporary technologies in place would make it clear that they could be deployed in ways that can reduce costs in building construction so as to achieve low cost of housing in the US as well as other parts of the world. For example, 3D application can be used for such a purpose to make homes affordable for Americans and residents of the country. In other words, the position of this paper is that emerging technologies can be used variously and judiciously to reduce the costs of production of goods and services in general and those in the

construction industry in particular. That is, emerging technologies are viable mechanisms for meeting the infrastructural development of the US, as their technical and judicious usage would guarantee affordability of houses by the poor and the rich alike.

Studies confirm that artificial (AI) technologies and smart technologies (ST) alongside their applications can be effectively integrated into construction for innovations in different onsite and offsite activities (Obiuto et al., 2024; Juhrich, 2023; Ivanova et al., 2023; Regona et al., 2023; Kochovski & Stankovski, 2021; Yigitcanlar et al., 2020). On the other hand, amidst the affirmed impact and potentials of AI and smart technologies in construction, many organizations are yet to key into them as supposed (Obiuto et al., 2024; Alsakka et al., 2023; Bidhendi & Azizi, 2021; Oberer & Erkollar, 2018; Zhang et al., 2015). Against the foregoing backdrop, this study proposes the leveraging of popular AI technologies for the attainment of cost-effectiveness that would change costs, rents and the trends slowing down rapid infrastructural development in the US.

Leaning on the confirmation, this study argues that many AI and ST can be leveraged for cost-effectiveness that would change the costs of building projects and materials, house rents, and the extent of infrastructural development in the US as well as other parts of the globe where AI and smart technologies are leveraged accordingly for cost-effectiveness. This argument is justified by the fact that given the proven potentials and impact of AI technologies in different fields and phases of construction, popular AI technologies and smart technologies have cost-effectiveness potentials for deserving changes in infrastructural development and housing affordability in the US and elsewhere in the world.

The importance of this study cannot be overemphasized, because it sets out to draw maximum attention to the undermined cost-effectiveness potentials of AI and smart technologies in lessening the rising high costs of building and houses in the US. Its overall proposal, as a viable means of solving a critical national problem, makes the study very important. It is of particular great importance to all Americans and residents who affected by the pressing housing issues that have traces to the current high costs of construction in the US.

Statement of the Problem

The increasing costs of building materials and both onsite and offsite construction projects and activities largely account for the whooping charges for houses and other categories of accommodation in the US. Consequently, housing affordability challenges consistently confront many Americans and residents in recent times. The ugly situations informed this study, which sees the dire need to address the issues at stake. It rises to proffer some scholarly solutions by making a case for the combined leveraging of AI and smart technologies for construction in order to attain cost-effectiveness, housing affordability, and rapid infrastructural development in USA. The foregoing points highlight the novelty of the study.

Aim

The aim of this study is to examine the cost-effectiveness of some popular AI and ST in building projects, which have the potentials of saving costs in construction projects. The objectives are to:

i. Ascertain the current cost of houses and building materials in the US.
ii. Explore the cost-effectiveness of some popular AI and ST in reducing the cost of building expenses.
iii. Correlate cost with rent and infrastructural development.

Research Questions

The study is guided by the following research questions:

i. How costly are houses and building materials currently in the US?
ii. Are there AI and smart technologies that save cost in building and construction?
iii. To what extent does cost correlate with rent and infrastructural development?

Review of Related Literature

The study done by Obiuto et al. (2024) proposes the leveraging of AI in construction management to improve project efficiency and cost-effectiveness. By its proposition, the study lends credence to the position of the current study that leveraging AI and ST can lead to reduction in the cost of building houses and rent charges in the US. Obiuto et al. (2024) go on to note that leveraging AI through ML, and data prediction and analysis would proffer solutions to project complexity, delays, and communication barriers, among other challenges faced in the construction industry. For the present study, the noted challenges account in part for the high cost of building and the subsequent high cost of rent in the US and beyond, which together slowdown infrastructural development in the country.

Just like the present study, Obiuto's et al. (2024) study proposes that the following AI strategies should be integrated into construction: data collection, ML algorithms and cloud computing. The implication of this proposal is that these identified strategies are some of the most popular, effective, influential and also cost-effective AI technologies of great relevance to construction. It follows that when deployed rightly and accordingly, these AI technologies and applications proffer solutions to problems such as high cost of building, which thereby help to reduce outrageous rent charges and make houses affordable for both the poor and the rich. That would also mean bridging the gap between the poor and the rich in terms of accommodation.

By identifying five major benefits of AI to construction, the study done by Singh (2024) lends credence to the position of the present study. That is, it implies that AI also offers cost-effectiveness to the construction industry, from which the public benefit significantly too. The benefits identified by Singh (2024) are real-time hazard detection, enhanced incident reporting and response, proactive risk mitigation, data-driven decision-making, and compliance management. Considering these benefits, the present study argues that AI

has the potentials of reducing costs. This assertion is in view of the fact that proactive detection and prevention of risks and hazards save costs, which influence the total expenses on construction projects. When project managers realize that the projection done using AI technologies helps to reduce costs, they become less expensive on those aspects of the construction next time when budgeting and charging clients.

Also, with the noted data-driven decision-making and management, AI technologies are proven to be capable of cost-effectiveness. By helping to ensure as well as enhance effective decision-making and management, costs are reduced directly and indirectly. The long-run impact manifests in cost-effectiveness, among others. Consider the following table for some major benefits of AI (technologies) in construction, as proven by extant literatures:

Table 1: Benefits of AI & ST in Construction

Benefits	Citations
Costs reduction, Saving time, Accurate forecasting, Effective project planning, Effective risks management	Kamble and Gaikwad (2024) Regona et al. (2023)
Data-driven decision-making, Compliance management, Real-time hazard detection, Enhanced incident reporting and response, Proactive mitigation of risks	Singh (2024) Kodete et al. (2024)
Cost-effectiveness, Safety management effectiveness	Kamble and Gaikwad (2024) George et al. (2022) Srivastava (2021) Yigitcanlar et al. (2020)
Improved project efficiency, Cost-effectiveness	Obiuto et al. (2024)
Addressing environmental degradation and public health concerns	Adefemi et al. (2023)
Help in prediction and detection Ensuring site safety	Juhrich (2023)
Reduction of costs, risks, and wastage of time and resources, Improved safety, performance, efficiency and project management, Allowing high productivity, innovations, growth, profits and realization of goals	Regona et al. (2022)

Source: Author's Compilation, 2024

From the Table 1 above, there is no doubt that AI is of great relevance to construction. It has been impacting hugely on construction through its technologies. It has been proffering

some solutions to the problems affecting the construction industry. The benefits of AI and ST rest on the functions played by their technologies and applications. Although the focus of the present study is on the cost-effectiveness benefits, a reflection on some other major benefits is made to show that apart from the cost-effectiveness benefits, AI and ST have many other benefits. There is no gainsaying the fact that some other benefits of AI and ST abound. However, those identified above are taken to suffice for the others, based on the scope focus of this paper.

More so, the study done by Adefemi et al. (2023) on the role of AI in improving public health through the green environment agenda shows that AI plays a critical role in construction in the US. Justifying its position with views in extant literatures, the study holds that AI technologies can be leveraged for addressing issues of environmental degradation and public health concerns. By proposing the leveraging of AI technologies for the attainment of safety in US, Adefemi et al. (2023) implicitly agree that AI and smart technologies can be leveraged for cost-effectiveness. Similarly, Regona et al. (2023) stress the need to leverage AI technologies in constriction to attain improved efficiency and productivity. This means that by attaining efficiency and productivity, they impact on cost-effectiveness in several regards. The reason is that cost either makes or mars efficiency and productivity.

The study done by Juhrich (2023) proves IoT, sensor technology and computer vision to be popular AI technologies playing critical role in construction, offering different opportunities. For the present study, the said opportunities include cost-effectiveness. This is because as they help in prediction, detection and ensuring site safety, the realized results have bearings to cost. Thus, IoT, sensor technology, and computer vision, among other AI technologies and applications, help determine and reduce costs. This study argues further that their role impact on construction costs transcends to reducing the costs of, or charges for, homes in the US and beyond. The implication is that if these technologies and applications are leveraged accordingly, cost-effectiveness is bound to be attained and infrastructural development would increase. Consider the following table for AI cost-effective technologies:

Table 2: Some AI Technologies Impacting on Construction

AI Techs	Cost-Based Findings	Citations
Deep Learning Algorithms Machine learning	Cost-effectiveness Safety management effectiveness Speedy tasks thereby saving costs and time	Kodete et al. (2024) Okusi (2024) George et al. (2022) Wusu et al. (2022) Bidhendi and Azizi (2021) Xu et al. (2021)
Digital image analysis Canny edge detector	Cost-effective safety monitoring	Alsakka et al. (2023) Baduge et al. (2022) Seo et al. (2015)

Automated machinery and systems; Faster R-CNN	Predict, reduce, control and impact on costs	Alsakka et al. (2023)
Natural language processing, Robotic process automation, Reinforcement learning, Computer vision	Cost-effectiveness, Performance efficiency, Cost-impacted decisions and predictions	Ivanova et al. (2023)

Source: Author's Compilation, 2024

As evident in Table 2 above, there are different AI technologies that are capable of cost-effectiveness, which can be leveraged to reduce costs of building construction and rents. This study does not claim exhaustion of the technologies that are cost-effective. Nevertheless, those presented are only the ones considered to be among the popular and multitasking technologies that have the capacity of being deployed variously for different purposes. When deployed variously, these technologies can yield different desired results. What matters most is how they are deployed and the purposes they are deployed for. Additional to the Table 2 above, the Table 3 below shows only cost-effective AI and smart technologies:

Table 3: Cost-effective AI and ST

AI techs	Smart techs
Machine learning, Natural language processing, Computer vision, Reinforcement learning, Robotic process automation	Building Automation Systems, Internet of Things, Renewable Energy Systems, Smart Water Management Systems
Pasupuleti et al. (2024)	Kodete et al. (2024)
Rasheed et al. (2024)	Alamleh et al. (2023)
Ivanova et al. (2023)	Pan and Zhang (2023)
Srivastava (2021)	Munir et al. (2022)
Qasim and Kharbat (2020)	Pan et al. (2022)
Nikitas et al. (2020)	Kochovski and Stankovski (2021)
Naser (2019)	Liu et al. (2020)
Kim et al. (2015)	Molana and Sadi-Nezhad (2018)

Source: Author's Compilation, 2024

Furthermore, studies show that the construction industry is faced with different sets of challenges (Regona, 2022; Regona et al., 2022; Pillai & Kira, 2020). Some are the challenges

of adopting technologies, while others are the conventional challenges associated with the industry that do not necessarily concern technologies. For example, Regona et al. (2023) note that the construction industry is yet to adopt AI and smart technologies and other computer-based means of construction because of high costs of technologies, lack of technical-know-how, being too used to their known traditional modes, and inherent environmental and socio-economic factors. It follows that the adoption of technology in the industry is currently low or inconsequential and technological innovations in the sector are yet to obtain in high proportion.

In the same vein, George et al. (2022) regret that the construction industry faces high fatalities, as a result of the over reliance on traditional methods of preventing accidents. They propose the leveraging of machine learning (ML) alongside other AI technologies for sustainable solutions to site accidents and hazards. That is, they are of the view that AI technologies like ML have the potentials of reducing the prevalence of accidents and of reducing risks at sites. Bidhendi and Azizi's (2021) study also proves ML, an AI technology and application, to be a popular one that performs functions such as costs reduction, time management, safety management, effective prediction and detection, and improved performance. They emphasize that it is because of its functions that governments and big organizations of different nations are spending hugely on it and encouraging its usage. Be it so, ML can be leveraged for cost-effectiveness that would lead to affordability of homes and increased infrastructural development in US as well as elsewhere.

Gap in Literature and Contribution of the Research

The review made so far shows that AI and ST play crucial role in different phases of construction. It is also realized that there exist a growing number of studies on AI and smart technologies in construction. There are more studies on AI technologies in construction sector than smart technologies in the sector. The existing literatures confirm that AI technologies and smart technologies can be leveraged for different profitable results in construction. Some of them also show that some AI technologies play essential functions that impact on costs. However, none of the studies focus on or propose the leveraging of AI and smart technologies for the reduction of the costs of building houses in US and as means of increasing infrastructural development in the country. It uniquely argues that by leveraging AI and ST accordingly for construction activities, infrastructural development would increase in the country because of the reduced costs of building materials and projects.

This all-important uncovered or unexplored aspect of the potentials of popular AI and smart technologies constitutes the gap in literature bridged by the current study. By limiting their concerns to the momentary benefits, functions, potentials and contribution of AI technologies, a gap in knowledge is created or left bare by existing literatures, such as those reviewed already in this study. On the other hand, by bridging the knowledge gap, the present study uniquely makes relevant contributions to knowledge and discourses on the

subject matter. It looks beyond the momentary to futuristic prospects and potentials of AI and smart technologies. Significantly, it looks at issues of costly housing in the US and proposes the leveraging of AI and smart technologies for cost-effectiveness in construction, which would lead to reduction in costs of building materials and projects, and house rents. By attaining these, the study argues, there would be increased infrastructural development in the US and the gap between the poor and the rich in affording good homes will decrease.

Methodology

Following the nature of the study, qualitative method is employed. In gathering data for the study, both primary and secondary data sources were relied on. The primary sources relied on are telephone interview, observation and introspection. The telephone interview involved 15 participants, out of whom 10 (representing 66.6%) are construction workers and 5 (33.4%), are experts in the field of AI. Both participant and non-participant observations were relied on for close objective observation of primary data. It also served as a means of data authentication.

The researcher being in the construction industry is familiar with the thematic concerns and thereby derived data from experiential learning and witnessed situations and events. This is where introspection came in additional to observation. Thematic and content analyses alongside interpretive and descriptive analytic tools are used for the analysis of the primary data. On the other hand, systematic review and content analysis are employed in analyzing the secondary data. The secondary data sources include journals, textbooks and theses gathered from the internet, and selected libraries.

Presentation and Analysis of Interview Results

The data presented here are the synthesized and analyzed responses of the 15 interviewees. The responses presented and analyzed thematically hereunder are only those on the research objectives and questions.

Theme 1: Current cost of houses and building materials in the US

On the current cost of houses and building materials in the US, 11 (73.4%) of the 15 (100%) participants lamented that it is very high and worrisome. Their responses align with the viewpoint of this researcher, who feels that the current costs of housing and building in the US are outrageous and deserve to be addressed by leveraging cost-effective AI and smart technologies to attain the purposes of costs reduction, low-cost and quality housing, and rapid infrastructural development. These participants agreed that a reduction in the costs of building projects and materials would proportionately lead to low rent, affordable housing and increased infrastructural development.

On the contrary, 4 (26.6%) of the 15 (100%) interviewees held otherwise that they saw nothing wrong with the current cost of housing in the US. Their perspective is bourgeois. It implies that they are not affected by the current costs of housing in the US. Regardless of

their bourgeois perspective on the cost of housing and building construction in the US, their overall number is inconsequential compared to that of the other 11 participants. Out of the 4 participants contesting the current cost, 3 are construction workers, while 1 is an expert in AI.

Thus, 7 of the 10 construction workers and 4 of the 5 experts in AI gave responses that justify the position of this paper that the current costs of houses and building materials are high. This finding answers the **research question 1: How costly are houses and building materials currently in the US?** By answering this research question, the finding also shows that the research objective 1 (**Ascertain the current cost of houses and building materials in the US**) of the study is met.

Theme 2: Cost-effectiveness of some popular AI and smart technologies in reducing the cost of building expenses

On the cost-effectiveness of AI and smart technologies being leveraged for reduction of costs of building expenses, 6 (40%) construction workers and all the 5 (33.4%) AI experts agreed that there are artificial intelligence and smart technologies that are cost-effective and can help solve issues of costs associated with building construction. In mentioning the AI and smart technologies that are cost-effective for the purpose, their individual responses show a consensus of the following as the most prominently assured technologies that can serve the purpose: Machine Learning, Natural Language Processing, Computer Vision, Reinforcement Learning, and Robotic Process Automation; and Building Automation Systems, Internet of Things, Renewable Energy Systems, and Smart Water Management Systems respectively. That is to say these aforementioned AI and smart technologies are the most popular and cost-effective ones, based on the finding from their mentioned technologies. They expressed a unanimous thought on the correlation between costs of building homes and costs of renting houses.

Their responses suggest that it is quite logical to think or aver that by reducing the costs of building expenses, rents can be reduced too, and infrastructural development would get increased because more people would build for both residential and non-residential purposes. The number of responses from the AI experts shows that they are all realistic or familiar with the diverse functions of AI and smart technologies. They are also more receptive to AI than construction workers. The responses of the construction workers highlight the fact that many of them are yet to accept AI and smart technologies in construction. The otherwise responses of 4 (26.6%) of the construction workers do not disprove those of the rest participants (6 of 40%and 5 of 33.4%). The responses of the 11 participants are upheld as the finding that answers the research question 2 (**Are there AI and smart technologies that save cost in building and construction?**) and proves the study as meeting the research objective 2 (**Explore the cost-effectiveness of some popular AI and smart technologies in reducing the cost of building expenses**).

Theme 3: Extent of cost correlation with rent and infrastructural development

Questions were asked to find answers to the research question 3 on the extent to which cost building correlates with rent and infrastructural development. The answers given by 8 (53.4%) construction workers and 2 (13.4%) AI experts proved that the cost of building correlates significantly with rents and either increases or decreases infrastructural development anywhere in the world. For example, majority of them said, "Rent increases when cost of building or living increases or is high"; "People build more when costs of materials and building construction are affordable". These responses affirm the assertion of the paper that cost correlates with rent and infrastructural development. This means that cost is a determinant of rent and infrastructural development anywhere in the world. Given this reality, the need to leverage AI and smart technologies for cost-effectiveness and rapid infrastructural development (in USA) cannot be undermined.

On the contrary, 2 (13.4%) construction workers and 3 (20%) AI experts held otherwise, stressing that they would not really be able to say or determine the correlation. It is realized that more AI experts than the construction workers could not determine the cost correlation. Perhaps, that is because the construction workers are more expertise in cost estimation, management, determination and analysis than the AI experts. Of course, every building project involves costs. It is not all the undertakings of AI experts involve cost in such regards. Be it as it may, the foregoing finding, from the responses of 10 (66.6%) of the 15 (100%) participants, proves that cost of building correlates with rent and infrastructural development. This is because high cost of building leads to high cost of housing and reduces infrastructural development, since many persons are unable to afford materials and construction charges. The reverse obtains when building expenses are affordable or cheap. The finding answers the research question 3 (**To what extent does cost correlate with rent and infrastructural development?**) and proves that the research objective 3 (**Correlate cost with rent and infrastructural development**) is met.

Conclusion

From both primary and secondary sources, this study has affirmed the place of AI and smart technologies in construction. The study shows machine learning, natural language processing, computer vision, reinforcement learning, and robotic process automation to be prominent cost-effective AI technologies. Besides, it proves that Building Automation Systems, Internet of Things, Renewable Energy Systems, and Smart Water Management Systems are cost-effective smart technologies. It is realized that when deployed rightly and accordingly, AI and ST can be used variously to attain different purposes. Their huge potentials and critical role in construction activities make it quite obvious that they are capable of being leveraged for cost-effectiveness that would reduce costs of building projects and materials, and house rents and increase infrastructural development.

Undoubtedly, costly building projects and materials lead to costly house rents and reduced infrastructural development, as many who do not have enough cannot build their houses.

As a way of proffering a lasting solution to the current housing challenges in the US, this study proposes the leveraging of AI and smart technologies for cost-effectiveness and increased infrastructural development in the country. The results of the study undoubtedly apply to some other countries of the globe. The study thereby makes unique contributions to discourses on the subject matter, and to addressing house challenges in the US.

Recommendations

The following recommendations are made:

- Organizations and government are charged to leverage AI and smart technologies for cost-effective building construction and rapid infrastructural development in the US.
- Project managers and other stakeholders of construction are charged to look into the rising cost of housing in the US and find ways of reducing the cost of rents so as for both the rich and the poor to be able to afford houses in the country. Doing so would address a lot of the issues associated with homelessness.
- More studies should be carried out on the cost-effectiveness of AI and smart technologies to uncover a lot of findings that would lead to betterment in the construction industry and impact positively on costs, housing and infrastructural development in the US as well as elsewhere in the globe.

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