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Harnessing Artificial Intelligence for Transformative Impact in the Ghanaian Construction Sector

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Abstract

The integration of artificial Intelligence (AI) in the construction industry holds significant promise for enhancing various aspects of project management and execution. AI offers unprecedented opportunities for streamlining processes, enhancing productivity, and elevating safety standards. The study explored AI implementation opportunities and how AI technologies can drive innovation, enhance decision-making processes, and propel the sector toward a more efficient and digitised future in the construction industry. To fill the gap, the study adopted a quantitative research approach to offer a holistic assessment of the effects and opportunities for the advancement of AI in Ghanaian construction settings. Based on the quantitative survey data obtained from 97 participants from 10 construction companies in the Central Region of Ghana and the literature review, the study revealed several benefits of AI implementation. The importance of using AI has been seen in design and planning, safety management, and the quality of delivered projects. Regression analysis also expands on the relationships between the identified AI-based efficiencies, underlining that increased utilisation can enhance productivity and safety and reduce adverse environmental impacts. Further, in the context of Ghana, the study outlined areas of importance for constructing AI in the construction industry: construction monitoring, energy efficiency, and supply chain. These findings have depicted the sector's awareness of AI and its value as a tool for improving effectiveness in operations and implementing sustainable measures. Overall, the knowledge generated by this study proves beneficial for directing strategic planning and advancing innovation in the context of the Ghanaian construction industry. In as much as it acknowledges the gap and the prevailing theoretical literature, it ushers in a guide for availing AI-driven growth in the construction sector in terms of productivity, quality, and sustainability in Ghana and the global space.

Keywords: *Artificial Intelligence; Construction Industry; Innovation; Sustainability.*
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I. INTRODUCTION

Artificial intelligence (AI) has develop as a force transforming various industries [1]. The construction industry has also not been left behind, as Artificial Intelligence (AI) has been identified as a revolutionary technology in different sectors [2,3]. AI stands for unprecedented technology to modernize construction activities and enhance safety standard within the construction ecosystem [4,5]. As recent trends indicate, machine learning, robotics and data analytics have made impressive breakthroughs that have put AI in a position whereby it can revolutionise construction projects through the attainment of efficiency, quality, and safety [6,7,8].To this end, the application of AI in the construction industry holds the potential to enhance resource management, reduce risk, and enhance project delivery, which in turn can positively impact the construction of a sustainable built environment [2,5]. This paper seeks to establish that AI holds potential and value beyond speculation on how the technologies can be harnessed for innovations that improve the decision-making processes in

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the construction Industry towards the digitalised future. The next section of the paper explains what artificial intelligence (AI) is, the benefits of AI, its applicability to the Ghanaian construction sector, and the opportunities for future development of AI in the Ghanaian construction industry.

II. LITERATURE REVIEW

A. An overview of Artificial Interligence (AI)

Artificial Intelligence (AI) is a branch of science like mathematics and biology; AI is a set of algorithms, approaches, and difficulties to solve numerous tasks. It is broken down into many sub-fields and can be categorised under the larger field of Computer Science (CS) [6]. AI is an issue discussed almost daily due to heavy coverage in the media and general popularity, which allows for no ignoring. According to [5], the number of papers on AI on Scopus rose almost seven times from 1996, and the number of documents on CS has increased five times in the same period.

B. Advantages of AI Implementation

The construction industry's rate of embracing AI-based technology is considered to be virtually nonexistent at approximately zero per cent [7]. Still, there is a belief that the construction industry could introduce AI advancements into its processes, making AI the next frontier in the construction industry [7]. Disclose the current state of AI and construction, highlighting the wide gap between the current practices within the construction industry and the potential benefits that AI technologies can bring. However, there has been increasing agreement among researchers and practitioners that integration with AI has the potential of opening new possibilities for efficiency improvement in construction projects. environing on prior successes in other industries, including manufacturing and finance, that have already experienced major changes due to AI penetration, the construction sector is gradually focusing on the application of AI in construction to improve project performance and minimise risks. With construction entering the digital age, there is no doubt that the digital tools built around AI will be part of the future direction of this industry [8] enumerate the benefits of AI as follows: greater performance, better safety, reduced cost, condition-based maintenance, integrated design and construction, better quality and less defects, better control of risks, higher production rates and sustainability, and knowledge management.

C. Areas of AI Advancement in the Ghanaian Construction Sector

AI has become a tool through which construction companies can improve efficiency, safety, and productivity by enhancing ways in which old problems have been managed by the firms [9]. AI algorithms integrated into project management can help identify the best time schedules and resource utilisation that will help reduce time wastage to a great extent [10,2]. Several applications of AI in construction can be used to predict different risks in construction projects based on data analysis from past projects and the specifications of the current project. They are helpful to project managers and help them identify risks and prevent disruptions to the project [11]. Using computer vision and sensors under the AI umbrella helps increase safety observation in construction sites, providing a safer working environment and lowering the probability of accidents [12, 13]. AI-based approaches, for example, can inspect construction materials and components for arrangements of defects or ways deviating from the construction design as per predetermined standards, hence enhancing the quality and eventually reducing instances of having to redo the construction [15]. Supply chain activities such as forecasting the need for materials, tracking inventory and recognising potential challenges in the procurement chaincan all be enhanced through the use of AI algorithms, which can make significant contributions to the reduction of costs and the optimisation of the process in construction firms [10, 2]. Some AI applications in maintenance comprise machine learning techniques to determine and point out possible failures of equipment before they occur, preventing machine breakdown and thus reducing equipment downtimes [15, 16]. From the sustainability point of view, AI can enhance the energy consumption of the building based on data collected by sensors and the Building Information Management System with relevant suggestions for energy-saving and environmentally friendly construction [17]. In addition, AI-enabled drones and satellite imaging can be used to oversee construction and assess progress. Since they give up-to-date status information on the project, these technologies can help stakeholders make the right decisions and meet project deadlines [18]. AI analytics can help handle big construction data to deduce useful information and trends, leading to rational decision procedures throughout projects [17]. In conclusion, the use of AI in the construction industry presents significant opportunities for advancing the scope of innovation in the sector and making pertinent and beneficial decisions that can positively impact the final performance of a project. Thus, the incorporation of AI technologies in construction companies aims to help organisations stand out in the market competition in the future [3].

D. Challenges of Implementing AI

While the potential benefits of AI in Ghana's construction industry are significant, the adoption of these technologies faces numerous challenges. One of the primary barriers is the high cost of AI implementation, which includes the purchase of advanced hardware, software, and ongoing maintenance expenses. Many construction firms in Ghana, particularly small to medium-sized enterprises (SMEs), struggle to allocate resources for such investments due to limited financial capacity [25]. Another key challenge is the skills gap. AI systems require a workforce with expertise in data analytics, machine learning, robotics, and AI technologies, yet there is a shortage of professionals with these specialized skills in Ghana [26]. This limits firms' ability to effectively implement and maintain AI technologies, reducing their potential impact on productivity and project outcomes. Furthermore, there is notable resistance to change within the industry. Construction professionals accustomed to traditional methods may be hesitant to adopt AI due to concerns about job displacement, skepticism of AI's effectiveness, or reluctance to invest in retraining [27]. Overcoming this resistance requires targeted awareness programs, showcasing the tangible benefits of AI and demonstrating how it can improve efficiency and safety without displacing human workers [28].

III. METHODOLOGY

This study used a quantitative research method, and deploying quantitative methods to fill a research gap was deemed appropriate for the topic under investigation. Considering that there is comparatively scant literature in this line of the study, an intensive research design was considered optimum to consolidate significant information. Twenty (20) construction firms were purposively selected from the Central and Western Regions of Ghana, based on their demonstrated commitment to enhancing technology and their specific interest in advancing artificial intelligence (AI) within the construction ecosystem. These firms served as the reference points for this study. To ensure comprehensive data collection, a census sampling technique was employed, targeting 100 professionals from within these selected construction companies.

The census approach was considered appropriate due to the relatively small population size of the study according to [29]. The respondents included a diverse group of professionals, all of whom are registered members of recognized professional bodies within these construction companies. These professionals included quantity surveyors, architects, construction/civil engineers, and project managers operating within the study area, ensuring a robust and representative sample for the study and to maintain professional ethics, expects and professional inputs suggestions were sorted and a sampled questionnaire was drafted which accommodated industry expect advise.

Primary data was directly obtained from the field through the distribution of questionnaires to participants. Secondary data was gathered through an extensive review of various research articles, journals, and newspapers to ensure the validity of the findings. Respondents were asked to give their views on the advantages of artificial intelligence (AI) implementation and areas for advancement in the Ghanaian Construction industry sector. Three (3) out of the one hundred (100) questionnaires were incomplete during the editing and coding of the questionnaires obtained from the field. Data analysis centered mainly on quantitative techniques to comprehensively understand the research topic. Quantitative analysis involves statistical methods to analyse numerical data obtained from the ninety-seven (97) questionnaires; the results provide descriptive analyses of various metrics such as mean values, Relative Importance Index (RII), standard deviation (SD), and the expected ranking of each variable. The Relative Importance Index (RII) is a statistical method used to rank and assess the importance of various factors in survey data, commonly in fields like construction management [20]. It is calculated by assigning weights to responses based on a Likert scale, then normalizing these scores to give a value between 0 and 1. The formula is

$$RII = \frac{\sum W}{\text{AxN`}}$$

where W is the weight assigned, A is the highest possible weight, and N is the total number of respondents. A higher RII indicates greater importance of a factor. This tool is useful for prioritizing variables, such as challenges or success factors, based on their perceived significance. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

IV. FINDINGS

A. *Respondents Background*

Table I provides the bio-data of the respondents in this study; the table shows that the majority (95.9%) of the respondents were males and within the age range of 31-40 (57 -58.8%) with higher national diploma certificates (43 - 44.3%). The majority (27 -27.8%) of the construction professionals were construction/civil engineers who have served their respective firms for 6 and -10 years (55 - 56.7%).

TABLE I: DEMOGRAPHIC DATA OF THE RESPONDENTS

Gender	**Frequency**	**Percent (%)**
Male	93	95.9
Female	4	4.1
Age Group (years)		
21 - 30	16	16.4
31 - 40	57	58.8
41 - 40	24	24.7
Qualification		
Diploma	10	10.3
Higher National Diploma	43	44.3
Bachelor's degree	33	34.0
Master's degree	11	11.3
Construction Professionals		
Construction/Civil engineers	27	27.8
Quantity surveyors	23	23.3
Project Managers	22	22.7
Architects	25	25.8
Years of Served in the Firm		
1-5 years	34	35.1
6 -10 years	55	56.7
11 -15 years	8	8.2
Total	**97**	**100**

B. *Advantages of AI Implementation in the Ghanaian Construction Sector*

AI implementation in the Ghanaian construction sector reveals significant advantages, as displayed in Table II, as indicated by the Relative Importance Index (RII) and mean scores. The most notable advantage, "Optimized Design and Planning," achieved the highest mean score of 5.2784 and an RII of 35.19, indicating its paramount importance in improving construction efficiency. Enhanced safety, with a mean score of 5.2680 and an RII of 35.12, ranks closely behind, emphasising AI's critical role in reducing workplace hazards. These findings

are consistent with similar studies that highlight AI's potential to revolutionise planning and safety management in construction projects [19].

Lower mean scores and RII values are observed for factors such as "New Job Creation" (Mean = 3.5567, RII = 23.71), which, although ranked 15th, underscores AI's potential in generating employment opportunities within the sector. The relatively high standard deviations observed in some areas, such as "Enhanced Safety" (Std. Dev. = 8.32981), suggest variability in expert opinions regarding AI's impact. However, the general ranking confirms AI's unique value in improving construction processes' quality, effectiveness, and sustainability [4]. The result of this analysis is seen as a shift in thinking towards the positive impacts of AI, supported by measurement standards that highlight its essential role in the development of the construction industry in Ghana.

TABLE II. ADVANTAGES OF IMPLEMENTING AI IN THE GHANAIAN CONSTRUCTION SECTORTOP OF FORM

	N	***Mean***	***RII***	***SD***	***Ranking***
Optimized Design and Planning	97	5.2784	35.19	7.72272	**1st**
Enhanced Safety	97	5.2680	35.12	8.32981	**2nd**
Improves Quality	97	4.8763	32.51	6.74268	**3rd**
Predictive Maintenance	97	4.8763	32.51	7.28906	**4th**
Enhance off-site Construction	97	4.4845	29.90	4.01848	**5th**
Cost Reduction	97	4.0103	26.74	.85993	**6th**
Increased Productivity	97	3.7835	25.22	.84443	**7th**
Data-driven Insights	97	3.7732	25.15	1.02576	**8th**
Enhance Sustainability	97	3.7010	24.67	1.00172	**9th**
Improved Efficiency	97	3.6392	24.26	.92630	**10th**
Post Construction Management	97	3.6289	24.19	.99289	**11th**
Enhance Quality Control	97	3.6082	24.05	1.02629	**12th**
Improves knowledge base	97	3.5979	23.99	1.06712	**13th**
Risk Management	97	3.5773	23.85	1.00866	**14th**
New Jobs Creation	97	3.5567	23.71	1.10839	**15th**

SD= Standard Deviation.

C. Correlation Analysis of the Advantages of Implementing AI

The findings presented in table III provides a valuable insight into the potential benefits of applying AI technologies within the construction sector. The data suggests a strong positive relationship exists between organisational productivity enhancement and parameters like Quality Assurance and Management, Risk Assessment and Mitigation, Corporate Responsibility and Sustainability, and Evidence-based Decision Making. The above trends indicate that integrating AI in construction activities may help optimise procedures, reduce mistakes, and enhance the efficient use of resources. As these correlations suggest, embracing AI could improve efficiency and, therefore, the general effectiveness of a project. The relations between enhanced safety and other elements, including risk control and efficient design, point to integrating safety measures with different issues concerning construction tasks. Adopting AI-powered prediction and preventative maintenance solutions can help identify potential safety threats and prevent serious risks, thus providing safer working environments. The need to connect greater security with sustainability means embracing AI technologies not just for apparent safety issues but for the constant improvement of sustainable environmental construction practices in the long term. The findings of this research on post-construction management or off-site construction point to the fact that AI can be useful in optimising most aspects of construction projects. Hence, the application of AI in post-construction management helps the stakeholders monitor and evaluate a construction project's performance, enhancing future decision-making. Analysing the links between off-site construction and some factors, such as risk management and quality assurance, one can infer that AI can significantly transform traditional construction approaches, making them less expensive and more productive. learning and teaching is yet to be fully harnessed in the Ghanaian context. The values lower minute standard deviations, and the confidence level averaged 1.06, and in the case of 'Estimating & Quantities', it shows that the respondents are more consistent with the importance of AI in these areas. At the same time, "Communication" and "Quality Control" are less prioritised, with the corresponding means 3.47 and 3.41, respectively, which means these aspects require further elaboration or improvement to unleash the potential of AI.

TABLE III: CORRELATIONAL ANALYSIS FOR THE ADVANTAGES OF AI IMPLEMENTATION IN THE GHANAIAN CONSTRUCTION SECTOR

		Improved Efficiency	Enhanced Safety	Coast Reduction	Predictive Maintenance	Optimized Design and Planning	Quality Control	Risk Management	Increased Productivity	Sustainability	Data-driven Insights	Improves Quality	Improves Quality	New Jobs Creation	Enhance off-site Construction	Post Construction Management
Improved Efficiency	Pearson Correlation	1	.204*	-.071	.091	-.101	.233*	.381**	.045	.219*	.297**	.253*	.231*	-.123	-.330**	.170
	Sig. (2-tailed)		.045	.492	.378	.325	.021	.000	.658	.031	.003	.012	.023	.231	.001	.096
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Enhanced Safety	Pearson Correlation	.204*	1	-.111	.060	.240*	.009	.144	-.129	.295**	.072	.020	-.056	-.018	-.144	.082
	Sig. (2-tailed)	.045		.280	.559	.018	.933	.161	.208	.003	.481	.849	.585	.860	.159	.424
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Coast Reduction	Pearson Correlation	-.071	-.111	1	-.055	-.147	-.255*	.113	.005	-.100	-.070	.243*	.047	-.064	-.035	-.075
	Sig. (2-tailed)	.492	.280		.595	.149	.012	.269	.960	.332	.493	.017	.651	.532	.735	.463
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Predictive Maintenance	Pearson Correlation	.091	.060	-.055	1	.087	-.044	-.045	-.174	-.253*	-.087	.215*	.083	-.116	-.006	-.242*
	Sig. (2-tailed)	.378	.559	.595		.397	.668	.659	.087	.012	.395	.035	.417	.260	.951	.017
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Optimized Design and Planing	Pearson Correlation	-.101	.240*	-.147	.087	1	-.171	.234*	-.215*	.280**	.051	-.011	.238*	-.205*	.316**	.226*
	Sig. (2-tailed)	.325	.018	.149	.397		.094	.021	.035	.006	.620	.913	.019	.044	.002	.026
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Quality Control	Pearson Correlation	.233*	.009	-.255*	-.044	-.171	1	.150	.331**	-.125	.152	-.007	.140	.107	.093	-.021
	Sig. (2-tailed)	.021	.933	.012	.668	.094		.142	.001	.222	.137	.944	.171	.296	.366	.834
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Risk Management	Pearson Correlation	.381**	.144	.113	-.045	.234*	.150	1	.157	.554**	.339**	.113	-.053	-.264**	-.304**	.258*
	Sig. (2-tailed)	.000	.161	.269	.659	.021	.142		.125	.000	.001	.270	.606	.009	.002	.011
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Increased Productivity	Pearson Correlation	.045	-.129	.005	-.174	-.215*	.331**	.157	1	.133	.240*	.191	-.091	-.018	.093	.171
	Sig. (2-tailed)	.658	.208	.960	.087	.035	.001	.125		.195	.018	.061	.377	.859	.364	.094
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Sustainability	Pearson Correlation	.219*	.295**	-.100	-.253*	.280**	-.125	.554**	.133	1	.511**	-.093	-.045	-.106	-.324**	.484**
	Sig. (2-tailed)	.031	.003	.332	.012	.006	.222	.000	.195		.000	.364	.659	.300	.001	.000
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97

Data-driven Insights	Pearson Correlation	.297**	.072	-.070	-.087	.051	.152	.339**	.240*	.511**	1	.215*	-.056	.091	-.104	.673**
	Sig. (2-tailed)	.003	.481	.493	.395	.620	.137	.001	.018	.000		.034	.588	.376	.312	.000
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Improves Quality	Pearson Correlation	.253*	.020	.243*	.215*	-.011	-.007	.113	.191	-.093	.215*	1	.345**	-.222*	.013	.273**
	Sig. (2-tailed)	.012	.849	.017	.035	.913	.944	.270	.061	.364	.034		.001	.029	.902	.007
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Improves Quality	Pearson Correlation	.231*	-.056	.047	.083	.238*	.140	-.053	-.091	-.045	-.056	.345**	1	-.325**	.301**	.113
	Sig. (2-tailed)	.023	.585	.651	.417	.019	.171	.606	.377	.659	.588	.001		.001	.003	.269
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
New Jobs Creation	Pearson Correlation	-.123	-.018	-.064	-.116	-.205*	.107	-.264**	-.018	-.106	.091	-.222*	-.325**	1	-.071	-.106
	Sig. (2-tailed)	.231	.860	.532	.260	.044	.296	.009	.859	.300	.376	.029	.001		.489	.302
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Enhance off-site Construction	Pearson Correlation	-.330**	-.144	-.035	-.006	.316**	.093	-.304**	.093	-.324**	-.104	.013	.301**	-.071	1	.100
	Sig. (2-tailed)	.001	.159	.735	.951	.002	.366	.002	.364	.001	.312	.902	.003	.489		.328
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Post Construction Management	Pearson Correlation	.170	.082	-.075	-.242*	.226*	-.021	.258*	.171	.484**	.673**	.273**	.113	-.106	.100	1
	Sig. (2-tailed)	.096	.424	.463	.017	.026	.834	.011	.094	.000	.000	.007	.269	.302	.328	
	N	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
*. Correlation is significant at the 0.05 level (2-tailed).																
**. Correlation is significant at the 0.01 level (2-tailed).																

D. *Areas for AI advancement in the Ghanaian Construction Industry*

As evident in the analysis of Table IV, the main thrust for AI improvement in the Ghanaian construction industry revolves around seven areas while underlining the general capabilities of AI in many realms. The priority area is "Construction Monitoring and Progress Tracking," which received the highest mean score of 5.38 and the RII of 38.44, indicating that the industry has embraced AI to improve real-time construction monitoring. This area is important since it enables different construction processes to be observed and controlled closely, resulting in improved project performance, as Zhang and his colleagues pointed out. The following high mean is 5.33 for 'Energy Efficiency and Sustainability', and RII of 38.07 for this factor, consistent with the global trend towards sustainable construction. These areas had more significant standard deviations, especially in "Construction Monitoring and Progress Tracking", which we recorded 8.31, showing many differences of opinions about the current and expected use of AI. On the other hand, the areas that appeared less important include supply chain management, project planning and scheduling, and estimation and quantities, with mean values of 4.55, 3.89, and 4.15, respectively, and RII ranging from 32. 47 and 27. 02. These areas are significant for enhancing the effectiveness and optimising the operations in the construction context, as other research has indicated (Zhang et al., 2021). This is not the case, though, as the relatively lower rankings indicate that the application of AI in these domains is still emerging or that the potential of AI to enable and enhance learning and teaching is yet to be fully harnessed in the Ghanaian context. The values lower minute standard deviations, and the confidence level averaged 1.06, and in the case of 'Estimating & Quantities', it shows that the respondents are more consistent with the importance of AI in these areas. At the same time, "Communication" and "Quality Control" are less prioritised, with the corresponding means 3.47 and 3.41, respectively, which means these aspects require further elaboration or improvement to unleash the potential of AI.

TABLE IV. AREAS FOR AI ADVANCEMENT IN THE GHANAIAN CONSTRUCTION INDUSTRY

	N	***Mean***	***RII***	***SD***	***Ranking***
Construction monitoring and progress tracking	97	5.3814	38.44	8.30593	1st
Energy efficiency and sustainability	97	5.3299	38.07	7.72404	2nd
Supply Chain Management	97	4.5464	32.47	3.45513	3rd
Project Planning and Scheduling	97	3.7938	27.10	1.05018	4th
Estimating and quantities	97	3.7835	27.02	1.06289	5th
Data analytics and decision support	97	3.7835	27.02	.91546	6th
Project management control	97	3.7216	26.58	1.02817	7th
Equipment Maintenance	97	3.6907	26.36	1.00375	8th
Design and Engineering	97	3.6598	26.14	.96703	9th
Safety Monitoring	97	3.6392	25.99	1.16535	10th
Risk Management	97	3.5464	25.33	.97916	11th
Job creation	97	3.5361	25.26	1.00064	12th
Communication	97	3.4742	24.81	1.05171	13th
Quality Control	97	3.4124	24.38	1.02827	14th

SD= Standard Deviation

E. *Chart showing areas for AI Advancement*

Fig. I. shows that construction monitoring and energy efficiency have been rated higher among the 14 areas for AI advancement in the Ghanaian construction industry, with relatively high mean scores indicating that respondents perceived areas as highly significant regarding AI technology advancement. The least among the 14 areas for AI advancement in the Ghanaian construction industry is quality control and communication, with lower mean scores, suggesting that respondents perceived these areas as less necessary in the context of AI technology advancement.

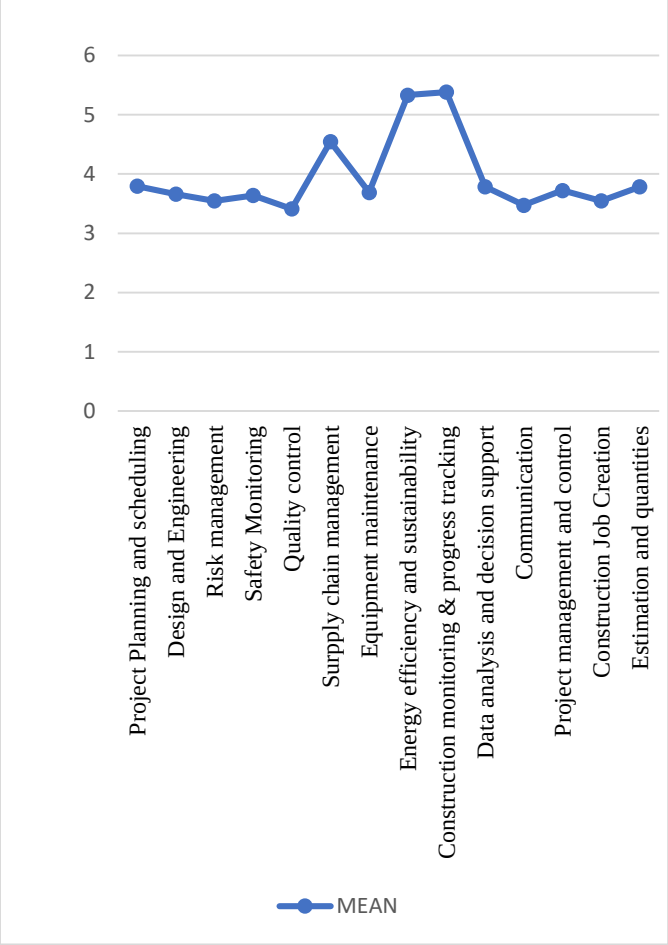

Fig. I. Areas of AI Advancement

F. Summary of findings

Optimized design and planning emerged as the most influential factors in the advantages of AI implementation in the Ghanaian construction sector. While the correlation analysis revealed some positive relationships between AI adoption and improved efficiency, the overall strength of these correlations was weak to moderate. The highest Pearson correlation value observed was 0.381, between risk management and improved efficiency, indicating a moderate correlation. However, most other relationships between AI implementation and variables like safety, post-construction management, and off-site construction showed weak or no significant correlation. Despite these limitations, the findings suggest that adopting AI has the potential to improve productivity and project outcomes, particularly in areas such as risk management and construction monitoring. For instance, implementing an AI-based Construction Safety Planning (CSP) model could help forecast safety threats, reducing risks and enhancing operational safety. This aligns with the literature, which highlights the role of AI in promoting sustainability and efficiency in construction projects [12,13]. However, given the weak correlations between AI and several other factors, further investigation is needed to better understand the specific conditions under which AI can significantly improve construction processes. This supports earlier findings by [21], who suggested that AI's impact may be more pronounced in certain aspects, such as off-site construction and quality assurance.

Also, AI technologies such as machine learning, robotics, and predictive algorithms are transforming various phases of construction by improving efficiency, accuracy, and safety. In some instances, machine learning is used for predictive maintenance by analyzing equipment data to forecast failures before they occur, reducing downtime [22]. Robotics, are also popularly used in tasks like bricklaying or demolition, automate repetitive labor-intensive processes, enhancing precision and speed while minimizing human error and injuries [23]. Predictive algorithms, on the other hand help optimize project timelines by analyzing past project data and weather patterns to anticipate delays and recommend adjustments [24]. These innovations highlight how AI can streamline construction operations, leading to more sustainable and cost-effective outcomes.

V. CONCLUSION

This study demonstrates that AI could revolutionize the construction industry in Ghana by improving key areas such as design and planning, safety, quality, environmental management, and predictive maintenance. The results highlight the positive relationships between AI adoption and increased efficiency, safety, sustainability, and productivity, underscoring the potential benefits of integrating AI into project deliverables. Moreover, the study identifies critical areas for AI development, including construction monitoring, energy efficiency, and supply chain management, positioning AI as a key driver for enhancing digitalization within the industry. These insights provide a foundation for practical strategies to foster innovation and sustainability in the Ghanaian construction sector.

While this study highlights the potential of AI in construction, it's important to address the following limitations in future research. First, the sample size of 97 respondents from 20 construction firms in the Central and Western Regions may limit the external validity of the findings, as other regions with different economic or industrial contexts might yield varied results. Additionally, the reliance on self-reported data introduces potential biases, such as social desirability bias or memory distortion. Furthermore, the scope of AI applications considered in this study was relatively narrow, focusing primarily on design and safety improvements. Expanding future research to include other AI applications, such as project scheduling, risk analysis, and quality control, could provide a more comprehensive understanding of AI's impact on construction performance and further improve the industry's productivity and sustainability.

Future research should address these shortcomings by increasing the number of participants, investigating various regions and companies, and discovering further AI utilisation opportunities in the construction industry.

REFERENCES

[1] M. Regona, T. Yigitcanlar, B. Xia, and R. Y. M. Li, "Opportunities and adoption challenges of AI in the construction industry: A PRISMA review," Journal of Open Innovation: Technology, Market, and Complexity, vol. 8, no. 1, p. 45, 2022.

[2] N. Rane, "Integrating Building Information Modelling (BIM) and Artificial Intelligence (AI) for Smart Construction Schedule, Cost, Quality, and Safety Management: Challenges and Opportunities," Cost, Quality, and Safety Management: Challenges and Opportunities, Sept. 2023.

[3] Y. Pan and L. Zhang, "Roles of artificial intelligence in construction engineering and management: A critical review and future trends," Automation in Construction, vol. 122, p. 103517, 2021.

[4] Y. Zhang, "The role of artificial intelligence in the construction industry: Opportunities and challenges," Journal of Construction Engineering and Management, vol. 147, no. 3, p. 04021010, 2021, doi: 10.1061/(ASCE)CO.1943-7862.0001972.

[5] S. O. Abioye, L. O. Oyedele, L. Akanbi, A. Ajayi, J. M. D. Delgado, M. Bilal, and A. Ahmed, "Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges," Journal of Building Engineering, vol. 44, p. 103299, 2021.

[6] A. Cesta, G. Cortellessa, A. Orlandini, and L. Tiberio, "Long-term evaluation of a telepresence robot for the elderly: methodology and ecological case study," International Journal of Social Robotics, vol. 8, pp. 421-441, 2016.

[7] J. L. Blanco, S. Fuchs, M. Parsons, and M. J. Ribeirinho, "Artificial intelligence: Construction technology's next frontier, A Theoretical Assessment on the Implementation of Artificial Intelligence (AI) for an Improved Learning Curve on Construction in South Africa," Available from: https://www.researchgate.net/publication/358361778 (accessed Apr 10, 2024).

[8] A. O. Onososen and I. Musonda, "Perceived benefits of automation and artificial intelligence in the AEC sector: An interpretive structural modeling approach," Frontiers in Built Environment, vol. 8, p. 864814, 2022.

[9] F. Shoushtari, A. Daghighi, and E. Ghafourian, "Application of Artificial Intelligence in Project Management," International Journal of Industrial Engineering and Operational Research, vol. 6, no. 2, pp. 49-63, 2024.

[10] Q. W. Ahmed, S. Garg, A. Rai, M. Ramachandran, N. Z. Jhanjhi, M. Masud, and M. Baz, "Ai-based resource allocation techniques in wireless sensor internet of things networks in energy efficiency with data optimization," Electronics, vol. 11, no. 13, p. 2071, 2022.

[11] Z. Allam and Z. A. Dhunny, "On big data, artificial intelligence and smart cities," Cities, vol. 89, pp. 80-91, 2019.

[12] A. Badri, B. Boudreau-Trudel, and A. S. Souissi, "Occupational health and safety in the industry 4.0 era: A cause for major concern?" Safety Science, vol. 109, pp. 403-411, 2018.

[13] A. Steimers and M. Schneider, "Sources of risk of AI systems," International Journal of Environmental Research and Public Health, vol. 19, no. 6, p. 3641, 2022.

[14] M. Javaid, A. Haleem, R. P. Singh, and R. Suman, "Artificial intelligence applications for industry 4.0: A literature-based study," Journal of Industrial Integration and Management, vol. 7, no. 01, pp. 83-111, 2022.

[15] B. Dhyani, "Predicting Equipment Failure in Manufacturing Plants: An AI-driven Maintenance Strategy," Mathematical Statistician and Engineering Applications, vol. 70, no. 2, pp. 1326-1334, 2021.

[16] K. Diljit, "Predictive Maintenance Revolution: How AI Transforms Industrial Systems," International Journal of Advanced Engineering Technologies and Innovations, vol. 1, no. 1, pp. 210-224, 2022.

[17] Y. Xiang, Y. Chen, J. Xu, and Z. Chen, "Research on sustainability evaluation of green building engineering based on artificial intelligence and energy consumption," Energy Reports, vol. 8, pp. 11378-11391, 2022.

[18] A. Waqar, I. Othman, N. Hamah Sor, A. M. Alshehri, H. R. Almujibah, B. S. Alotaibi, and M. Aljarbou, "Modeling relation among implementing AI-based drones and sustainable construction project success," Frontiers in Built Environment, vol. 9, p. 1208807, 2023.

[19] X. Chen, Y. Li, J. Wang, and Q. Zhang, "Sustainable construction management: Examining the role of technology and innovation," Sustainable Cities and Society, vol. 52, p. 101865, 2020, doi: 10.1016/j.scs.2019.101865.

[20] M. Gündüz, Y. Nielsen, and M. Özdemir, "Quantification of delay factors using the relative importance index method for construction projects in Turkey," J. Manage. Eng., vol. 29, no. 2, pp. 133-139, 2013, doi: 10.1061/(ASCE)ME.1943-5479.0000129.

[21] J. L. Blanco, S. Fuchs, M. Parsons, and A. Ribeirinho, "Artificial intelligence: Construction technology's next frontier," McKinsey & Company, pp. 1-7, Apr. 2018. [Online]. Available: https://www.mckinsey.com

[22] J. Zhou, Y. Ding, and Q. Yin, "Machine learning methods for intelligent predictive maintenance in the era of industry 4.0: A review," IEEE Access, vol. 8, pp. 123380-123396, 2020

[23] T. Bock and T. Linner, Robot-oriented design: Design and management tools for the deployment of automation and robotics in construction. Cambridge, U.K.: Cambridge Univ. Press, 2015.

[24] Y. Huang and Y. Kao, "AI-based predictive scheduling system for project planning," Automation in Construction, vol. 96, pp. 134-144, 2018.

[25] A. Obeng, P. Boateng, and A. Asiedu, "Challenges in adopting artificial intelligence in the construction sector: A case study of Ghana," Int. J. Constr. Manage., vol. 20, no. 3, pp. 245-253, 2020.

[26] E. A. Asare and B. O. Prempeh, "Bridging the skills gap for AI adoption in Ghana's construction industry," Ghana J. Technol., vol. 14, no. 2, pp. 101-112, 2022.

[27] T. Acheampong, "Resistance to AI integration in traditional sectors: A focus on the construction industry in Ghana," Afr. J. Sci. Technol. Innov. Dev., vol. 13, no. 4, pp. 415-425, 2021.

[28] K. Mensah and T. Anning-Dorson, "Technological innovation and resistance to change in the construction industry," J. Bus. Technol. Innov., vol. 7, no. 1, pp. 57-64, 2019.

[29] E. R. Babbie, The Practice of Social Research, 14th ed. Boston, MA: Cengage Learning, 2014.