International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

The Role of AI in Transforming Construction Innovation and Enhancing Safety Standards in Ghana.

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A B S T R A C T

Technology has been instrumental in shaping construction practices worldwide, yet its adoption for innovation and safety management remains underutilized in Ghana's construction industry. This study investigates the transformative potential of artificial intelligence (AI) in addressing critical challenges such as inefficiencies, low productivity, and inadequate safety standards. Through a comprehensive review of existing literature, case studies, and contextual analysis, the study highlights how AI technologies, such as predictive analytics, machine learning, and computer vision, can optimize construction workflows, mitigate risks, and improve decision-making processes. Four specific objectives guide the research: (1)To assess the current state of AI adoption in Ghana's construction industry.2)To analyze the impact of AI on enhancing construction safety standards in the country.3)To identify the challenges and barriers to AI implementation within the Ghanaian construction sector.4)To propose strategies for integrating AI to advance both safety and innovation in the construction industryData were collected using a structured survey administered to 164 construction professionals and stakeholders. This was further complemented by insights from case studies and an extensive review of relevant literature. The survey responses were analysed using both descriptive and inferential statistical methods to provide a comprehensive understanding of the findings. The findings reveal a strong preference for AI applications in project management and resource allocation, which are seen as critical to improving efficiency and sustainability. However, adoption in areas like safety monitoring, robotics, and general construction tasks remains limited due to high costs and inadequate infrastructure. The study highlights AI's potential to enhance construction safety, with technologies for hazard detection and predictive analytics receiving high ratings from respondents. Despite this, barriers such as a lack of skilled workers, financial constraints, and resistance to change pose significant challenges. Strategies for overcoming these barriers include targeted workforce development, leveraging predictive safety systems, and adopting AI-driven robotics to streamline workflows. These findings underscore the need for a comprehensive approach to AI integration, combining policy support, training programs, and financial incentives to foster widespread adoption. By addressing existing challenges and prioritizing safety-focused applications, Ghana's construction sector can harness AI to improve operational standards, reduce risks, and drive innovation. This study contributes to the growing discourse on AI in construction, providing actionable insights for stakeholders aiming to enhance the industry's readiness for technological transformation.

Keywords: Artificial Intelligence, Ghana Construction Industry, Construction safety, AI Adoption, Construction Innovation

1. Introduction

It is commonly acknowledged that the construction business is one of the most dangerous, mostly because of the high rate of workplace accidents that frequently arise from the intricate and dynamic nature of construction projects. A high-risk environment where accidents are frequent is created by project scope revisions, changing site circumstances, and the involvement of several stakeholders (CPWR, 2018; Demirkesen and Arditi, 2015; Tezel et al., 2021; Toscano et al., 1996). Because of this, safety issues in the construction sector have gained tremendous attention from industry stakeholders and regulatory agencies around the world (Zhou et al., 2012). In the past, regular safety inspections and employees' capacity to recognize and address possible risks have been crucial to maintaining worker safety on building projects. Despite being crucial, this conventional method has drawbacks because it mostly depends on human judgement and the frequency of inspections, which frequently leaves space for mistakes or overlooks. The necessity for increasingly sophisticated, proactive safety management techniques to successfully reduce hazards and safeguard employees is highlighted by the growing complexity of building projects. In Ghana, a considerable number of accidents and worker fatalities occur in the construction business, even though professionals in the field are fully aware of the many safety management systems required by regulatory acts. Although the building industry is vital to the nation's socioeconomic growth, many construction sites continue to be dangerous by nature, frequently leading to fatalities and serious injuries. This persistent problem draws attention to how risky building is in Ghana, where safety rules might not be properly applied or routinely enforced. Concern over health and safety procedures in the construction sector has grown over the past few years, and requests for regulation change have persisted. These worries are shared not only in Ghana but also globally, as the construction sector remains one of the most dangerous, highlighting the urgent need for more extensive safety measures to shield employees from the serious risks they encounter on a daily basis.

When compared to other industries, the construction sector is consistently among the least digitalized, which makes it extremely difficult for it to successfully handle many of the enduring issues it faces (Abioye et al., 2021). Construction has been sluggish to embrace new technology, which has led to inefficiencies and delays in problem-solving procedures, in contrast to more developed industries that have embraced digital transformation. Nonetheless, the potential of developing technology to improve safety in the construction industry is becoming more widely acknowledged. These technology developments are proven to be crucial in enhancing safety protocols and assisting in reducing the dangers associated with building activities, claim Oesterreich and Teuteberg (2016). The construction sector can address two primary areas of concern by incorporating digital tools and upcoming innovations, which will improve safety results and operational efficiency. The use of cutting-edge technologies has a lot to offer the construction sector, particularly in terms of improving safety performance. By proactively addressing possible hazards, these innovations present a fantastic chance to raise the safety standards on building sites. Consequently, a deeper examination of the connection between these new technologies and construction safety is becoming more and more necessary. By detecting risks before they materialize, simplifying safety procedures, and encouraging a safer working environment for all employees engaged in construction projects, the use of such technology may result in a decrease in or even the prevention of work-related accidents and hazards. The industry's future depends on this nexus of safety and technology.

To improve profitability, efficiency, safety, and security, artificial intelligence (AI) techniques—such as machine learning, knowledge-based systems, computer vision, robotics, and optimization—have been effectively applied in a variety of industries (Abioye et al., 2021). These AI technologies have a lot of promise for the construction sector. They can be used for risk management, resource and waste optimisation, activity monitoring, and safety inspections, including making sure ladders are used and secured properly. (Abioye et al., 2021; Majumder, 2022AI integration into building procedures can help the sector run more efficiently while also raising on-site safety requirements. To solve the long-standing safety issues in the construction sector, artificial intelligence (AI) must be incorporated into health and safety procedures. Poor safety standards in the construction industry are well known, and they frequently lead to mishaps and fatalities. Artificial intelligence (AI)-powered solutions provide creative ways to control safety hazards and drastically lower the frequency of these mishaps (Hire et al., 2022). The industry can take proactive measures to improve overall safety performance and create safer work environments by utilising AI. This study intends to investigate construction professionals' perceptions on artificial intelligence's (AI) role in fostering innovation and enhancing safety outcomes in order to advance the use of AI to improve safety and innovation in Ghana's construction industry. The study establishes four distinct goals in order to do this.:

1)To assess the current state of AI adoption in Ghana's construction industry.2) To analyze the impact of AI on enhancing construction safety standards in the country.3) To identify the challenges and barriers to AI implementation within the Ghanaian construction sector.4)To propose strategies for integrating AI to advance both safety and innovation in the construction industry. These objectives will provide valuable insights into the potential and challenges of AI in transforming Ghana's construction landscape.

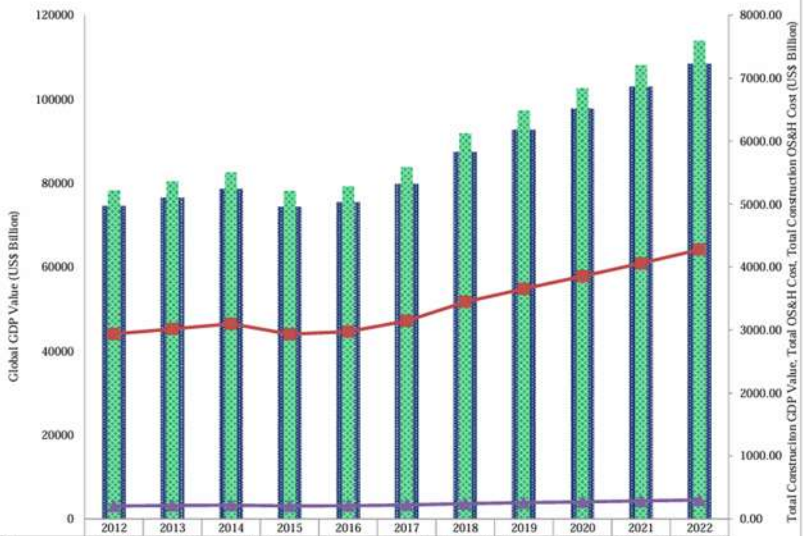
1.1 Overview of the Global Construction Sector

A McKinsey worldwide Institute poll estimates that in 2017, the worldwide construction sector contributed roughly 13% of the global Gross Domestic Product (GDP), and by 2020, that percentage is predicted to increase to 15%. About 7% of the world's workforce is employed in this industry, which also offers a variety of job prospects (Vaquero, T.S.; Silva, J.R.; Beck, J.C, 2013. Despite making a substantial economic contribution, the sector suffers from low labour productivity, which wastes money, labour, and materials throughout building projects. Implementing efficient construction management techniques is essential to improving performance because of its economic impact. An additional $1.6 trillion may be added to the industry's value each year if construction productivity increased by 50–60% or more, which would further increase global GDP. (F. Barbosa, J. Woetzel, Mischke,2017).

Globalisation, digitalisation, and industrialisation have all significantly changed the building sector. The industry is anticipated to undergo additional changes over the next five years, such as a shift towards product-based strategies, greater specialisation, stricter supply chain and value chain control, consolidation, a greater emphasis on customer-centricity, increased investment in technology and human resources, global expansion, and a greater emphasis on sustainability (Balaguer, C., 2004). Over the past three decades, global construction productivity has grown by an average of just 1% per year, despite the industry's expansion. The sector's inadequate adoption of new technology is largely to blame for this delayed progress . It is anticipated that the construction industry would become more standardised, consolidated, and integrated in the future, moving towards a product-based strategy. The method will become more efficient as more structures and parts are produced offsite. Furthermore, the industry will grow more worldwide as a result of the value chain becoming more consolidated (Shukla, A.K.; Janmaijaya, M.; Abraham, A.; Muhuri, P.K, 2019). Future design optimisation will be greatly aided by customer behaviour data and analytics, as AI technology is largely responsible for the expansion of the construction ecosystem. A more efficient and integrated value chain will result from the shift to a data-driven decision-making process, which will be largely facilitated by digitalisation.

1.2 Worldwide Perspectives on Construction Health and Safety

Because of the high rate of occupational fatalities and injuries in the construction sector, health and safety issues have attracted a lot of international attention. The construction industry is more risky than other industries, as noted by Bagir et al. (2020). Risk factors include poor posture, the use of heavy machinery, falls from heights, manual handling of heavy loads, and exposure to unfavourable weather conditions. The International Labour Organisation (ILO, 2018) reports that work-related illnesses and accidents claim the lives of about 2.78 million people year, or 7,616 people per day. Furthermore, around 374 million work-related illnesses and injuries occur each year, resulting in extended absences from work (ILO, 2018 The International Labour Organisation (ILO, 2018) estimates that poor occupational health and safety standards cause an economic loss equal to 3.94% of global GDP annually, despite the fact that human life is priceless and cannot be quantified in monetary terms. Over the ten-year period (2012–2022), the global GDP is expected to expand at a rate of 46%, from USD 74,535.41 billion in 2012 to USD 108,523.32 billion by 2022. This estimate indicates that during this period, inadequate workplace safety and health conditions will cost USD 37,396.71 billion (Statista, 2018-b). Approximately USD 6,094.04 billion would be saved over the following three years (2020–2022) if the current rate, which is 3.94% of world GDP, were cut in half. The total cost of construction is expected to reach USD 299.31 billion by 2022 if the cost of occupational safety and health in the sector is assumed to be comparable to that of other sectors at about 3.94%, however it is probably higher (Figure 1.1). Potential savings in occupational safety and health expenses for the three-year period from 2020 to 2022 might reach USD 291.58 billion if this percentage is cut in half, from about 3.94% to 1.97%. It is important to understand that certain incidents that result in fatalities and impairments cannot be adequately quantified in monetary terms when calculating the cost of occupational safety and health. Only those with impairments and their families can fully comprehend the personal agony they face, and this suffering frequently lasts a lifetime. In the same way, it is impossible to put a monetary value on the sorrow felt by the family of the deceased. Therefore, it is not possible to convert their suffering into monetary losses. Consequently, it is important to consider occupational safety and health from both a financial and a comprehensive standpoint, as it has significant effects on both individuals and society at large.



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Global GDP Value (US$ Billion)	74535.41	76596.14	78663.17	74429.03	75485.01	79865.48	87504.57	92734.03	97789.46	103029.66	108523.32
Total Construction GDP Value (US$ Billion)	5217.48	5361.73	5506.42	5210.03	5283.95	5590.58	6125.32	6491.38	6845.26	7212.08	7596.63
Total OS&H Cost (US$ Billion)	2936.70	3017.89	3099.33	2932.50	2974.11	3146.70	3447.68	3653.72	3852.90	4059.37	4275.82
Total Construction OS&H Cost (US$ Billion)	205.57	211.25	216.95	205.28	208.19	220.27	241.34	255.76	269.70	284.16	299.31

Fig. 1:1 Global GDP and Cost of Poor Occupational Safety and Health Practices (Deloitte, 2017)

It is often acknowledged that one of the most dangerous industries is construction. Poor occupational safety and health (OS&H) conditions on construction sites cause over 100,000 worker deaths annually, or around 274 deaths every day, according to figures from the International Labour Organisation (ILO) in 2015. This number represents over 30% of all workplace fatalities worldwide. According to statistics, compared to workers in other industries, construction workers in developed nations have a three to four times higher risk of dying in on-site accidents. The chance of dying in an accident involving construction is even higher in underdeveloped countries—three to six times higher than in industrialised ones (ILO, 2015). Numerous employees also get sick or pass away as a result of being exposed to chemicals and asbestos, among other dangerous substances. When compared to other industries, the construction sector routinely has the highest number of worker deaths in most nations. For instance, with 991 fatalities in 2016, the construction sector in the US had the largest number of worker deaths, up 6% from the year before. According to BLS (2018), these deaths accounted for 20% of all occupational fatalities in the United States.

1.3 Health and Safety in the Ghanaian Construction Industry

According to Agyekum et al. (2022), the Ghanaian construction industry's current health and safety situation indicates a moderate level of adoption of technologies like virtual reality, wearable safety devices, geographic information systems (GIS), sensing technologies, and building information modelling (BIM). Despite their potential to significantly raise safety standards, these instruments are still not widely used. This highlights the need for cutting-edge solutions to improve safety and efficiency in the construction industry and offers a clear opportunity to further integrate these technology. Several major obstacles stand in the way of Ghana's construction industry's adoption of cutting-edge health and safety solutions. Widespread implementation is hampered by high prices, a lacklustre innovation culture, insufficient ongoing training, opposition to change, and a lack of government backing and legislation. (Osei - Asibey et al., 2021; Mustapha, 2016Furthermore, deeper structural problems, such as a lack of comprehensive safety and health regulations, poor risk assessment procedures, a lack of skilled safety specialists, and inadequate staff training, are often blamed for accidents and hazards (Boadu et al., 2021a). These fundamental causes of persistent safety hazards highlight the industry's urgent need for structural change. Institutional obstacles and lax enforcement of occupational health and safety (OHS) regulations hinder its application in Ghana's construction industry (Bang & Nemade, 2023). Furthermore, safety is not considered a major commercial priority in the industry, and the safety culture is still in its early "pathological" stage (Williams et al., 2019; Mustapha, 2016). This reflects a minimal emphasis on safety, highlighting the urgent need for stronger regulatory frameworks and a shift in industry attitudes toward health and safety practices.

Research on the application of artificial intelligence (AI) in construction health and safety in Ghana has uncovered several important insights. One study highlighted a widespread lack of health and safety management across all levels of the construction process, with construction workers, supervisors, and companies exhibiting poor safety cultures and attitudes (Aasonaa, 2023). Another study stressed the importance of decolonizing occupational safety and health (OSH) research and practices to foster a stronger safety culture in non-Western contexts like Ghana (Sherratt & Aboagye‐Nimo, 2022). These findings underscore the need for tailored approaches to improving safety standards in the region. According to research, management commitment and support are the most important elements influencing safety performance in the construction sector (Boakye et al., 2022). Certain safety culture indicators were emphasised as being crucial for improving health and safety performance in a study that concentrated on small- and medium-sized enterprise (SME) contractors in Ghana. These metrics offer a starting point for developing a constructive safety culture in the building industry (Adzivor et al., 2022).By reducing worker exposure to hazardous conditions and implementing more industrialised procedures, artificial intelligence (AI) technologies present promising ways to increase safety and productivity in the construction sector (Hatami et al., 2022). On building sites, these improvements can greatly lower dangers while increasing productivity.

The construction industry has yet to fully embrace AI technologies, despite their potential (Boadu & Wang, 2021). There are several obstacles to implementing occupational health and safety (OHS) requirements in Ghana, including institutional limitations and ineffective enforcement methods (Phinias, 2023). There are many advantages to using leading safety indicators in construction, such as early warning systems, regulatory compliance, and accident prevention. Their successful implementation is hampered by issues such the requirement for sufficient training and communication, more time and expense, and low worker involvement (Simpson & Sam, 2019). Although the results are limited to particular regions, restricting a more comprehensive understanding of the issue, Ghanaian construction sites' health and safety (H&S) management methods are generally seen favourably (Chen & Chan, 2022). Although a lot of study has been done on automation in safety planning, most of it has focused on permanent structures. When it comes to temporary buildings, which are also essential in building projects, this creates a void in the literature. Furthermore, there is still much to learn about the use of AI in safety planning, which offers a great chance for future studies to improve both temporary and permanent safety systems by integrating AI.

1.4 AI Application in Construction

A system or framework that can autonomously carry out activities in complex and dynamic situations without constant human interaction or supervision is commonly referred to as artificial intelligence (AI), while the term covers a wide range of technologies and capabilities. According to the University of Helsinki (2018), this definition emphasises AI's capacity for adaptation, learning, and decision-making based on data inputs, enabling it to operate independently in a variety of settings, from automation in sectors like construction to decision-making processes. This independence is what distinguishes artificial intelligence (AI) from conventional computer systems, which mostly depend on human input for direction and judgement. Most people agree that artificial intelligence (AI) is a potent instrument for increasing productivity at every step of the lifespan of a building project. AI has the potential to greatly increase efficiency by optimising procedures including design, project management, and on-site operations. By maximising resource utilisation and cutting waste, this in turn improves sustainability, which benefits not just the environment but also the economy and society. Long-term growth and development can be promoted by AI-driven innovations that reduce costs, increase safety, and produce more sustainable building techniques (Blanco et al., 2018; Oprach et al., 2019). It is expected that AI would benefit organisations, projects, and the entire industry. The construction business is an important economic sector that contributes significantly to the GDP of many nations. Though it has a high number of occupational fatalities each year, it also has a substantial impact on trash generation, energy use, and resource consumption (Barker et al., 2007; Becqué et al., 2016; Dong et al., 2019). The industry may overcome these obstacles by using AI, improving safety, sustainability, and sector-wide efficiency.

AI is predicted to change the way the construction sector handles important topics like risk assessment, planning, scheduling, sustainability, and health and safety regulations. It also contributes to lifespan estimates, cost control, strategy formulation, and project performance optimisation. AI can help the sector make better decisions, increase operational effectiveness, and better handle long-term sustainability objectives (Hossain and Nadeem, 2019). According to Tidemann (2019), machine learning algorithms are made to learn from data and modify their models as necessary. The most often used machine learning approaches in the construction sector are neural networks, support vector machines, and fuzzy logic (Akinade, 2017). Knowledge-based systems also mimic human problem-solving skills by using a wealth of information to provide answers for difficult problems., (Sowa, 2000). These technologies collectively enhance decision-making and problem-solving capabilities in construction.

Expert systems, rule-based systems, case-based reasoning, and semantic networks are examples of knowledge-based techniques that are frequently employed in the construction sector (Akinade, 2017). Another important field of AI application is evolutionary algorithms, which draw inspiration from biological evolution (Russel and Norvig, 2010). According to Dasgupta and Michalewicz (1997), these methods are intended to maximise variables and investigate potential outcomes in order to determine the optimum results. Genetic algorithms, ant colony optimisation, particle swarm optimisation, and artificial bee colonies are only a few of the many techniques that fall under the broad category of evolutionary AI algorithms (Akinade, 2017). These methods provide effective resources for improving judgement and problem-solving in intricate construction settings.

1.5 Barrier to implementing AI for construction Safety.

The construction business is undergoing a transformation due to artificial intelligence (AI). Numerous studies have demonstrated how innovation may enhance safety, effectiveness, and other crucial aspects of corporate success. (T.D Teubeberg,2016). But before advancements in artificial intelligence technologies can be made, a number of barriers that prevent broad use must be overcome.

1.5.1 Prejudice against the Adoption of AI Technologies.

The main problem is that people are constantly afraid of new slim people. Unknown contemporary technological advancements have left many people unhappy. This was also true during the industrial revolution, to go back in time. Many people have negative thoughts or sensations before experimenting with new technologies. (M.Sheddysheva,2016). Human resistance is one of the main obstacles to the adoption of developing technologies, according to (A.R Maskuriy,2019). Modern tools are first viewed as insufficient since they present challenges and issues for novice users, such as inconsistent access and application errors. The first problem is that new users don't know how to utilise them and grumble about how bad the new tools are compared to the old ones. However, even with the newest tools or programming, zero breakdowns are unachievable. Typical instances of resistance to change and reluctance towards new tools include users who seem hesitant about the necessity of switching to a new system, users who are unsure of the benefits of new technology for their jobs, and users who are comfortable with their current tools or technology and are reluctant to switch to a new one. In addition, people frequently fail to learn how to use technology because of their hectic job schedules. Heavy workloads or task time pressure would make people less interested in setting aside time to learn how to use new things since they prioritise job achievement. On the basis of fear, the construction sector has a systematic opposition to new technical developments that must be addressed. Rapid change is not a hallmark of the construction industry's culture. Compared to many other businesses, the construction sector is far less active in developing and utilising innovative technology. Compared to industries like high tech and telecommunication, the automotive sector, and the financial services sector, the construction sector is more conservative. Since technologies are frequently used in critical infrastructures and major market environments, people in the construction sector are especially wary of disruptive, large-scale innovations that conflict with customary ways.

Additionally, he discovered in his research that a lot of people were still worried about the potential effects of technology. Because AI may be an existential threat to humanity, workers were worried that the technology will eliminate their jobs. Employees' strong unfavourable reactions to the company's potential use of AI technology have been caused by fear.

1.5.2 Lack of Executive and Government Support

Because of the high cost of the technology itself and the time it takes to adjust to the new style of working, implementing a technological transition in an organisation is quite expensive. Employers and the government, as paymasters and initiators, are therefore unquestionably crucial to the adoption of developing technology. inadequate management group. A business finds it challenging to overcome issues and fully embrace AI technology. According to the literature, the top management team is made up of important managers who have overall accountability for the organisation, like the CEO and CFO.
(Rogers et al.,2015).

(Wong et al.,2016) and (Latiff A.A et al.,2015) provide unmistakable proof that successful product innovation, as well as the successful installation and assimilation of information systems, are facilitated by top management assistance.

Organizational leaders' reluctance to embrace the use of AI technologies was partly due to their ignorance of these new technologies. According to research, many construction industry participants reject the use of contemporary technology because they are unaware of their benefits for construction projects (Latiff A.A et al.,2015). This frequently occurred when the organization had a higher number of top managers. Because of their different birth ages and educational backgrounds, senior managers are less exposed to emerging technologies than younger managers. It also more difficult to persuade them to switch from conventional construction methods to AI technologies.

Furthermore, evidence indicates that businesses implementing AI technology have difficulties gaining support and buy-in from stakeholders (Zhou et al,.2015). Many stakeholders recognise the potential of developing technologies, but many are reluctant to risk multibillion-dollar investments on apps they believe to be unproven. Resource constraints could be a major problem for the widespread adoption of AI technology by consumers. Attempts to integrate AI solutions necessitate a variety of costs, including hiring, retraining, and upskilling employees, overhauling old systems or technology, and the cost of deployment and administration. It is frequently challenging to practise implementing emerging technologies in the organisation when partners do not provide financial or infrastructure resources.

The absence of government funding, which hinders the broad adoption of AI in the construction sector, is another significant obstacle. One barrier to the industry's efforts to encourage the use of AI is a lack of financing for AI systems. Architects, engineers, and construction (AEC) firms have not received subsidies from the Malaysian government to deploy AI systems or to invest in R&D for building. For this reason, the majority of local construction companies, particularly medium- and small-sized ones, favour using the traditional approach to project management (Chan et al.,2017) (R Eadie et al.2015).

Additionally, there was no practical push from the government on building organisations to practise using AI technologies for construction projects [18]. For instance, there are currently few companies using Building Information Modelling (BIM) in the construction sector, and there are no laws requiring the use of BIM in any kind of project

(Smith .P,2014). The government has not effectively utilised its capacity to promote the adoption of BIM in the fields of finance, education, training, and the economy.

1.5.3 Lack of Security

Security is yet another major concern with the use of AI from an IT perspective. When it comes to the use of AI systems, concerns about ownership and risk management are common (C. Lui et al.) The biggest challenges with big data are privacy and data security. There is still a need for additional improvement in all areas, from software to hardware, as industrial big data research and implementations are currently not very advanced (P.D .Zhou,2014). There are a lot of problems that need to be fixed with regard to "how to maintain network security" and "how to deal with cyber espionage to prevent hackers and other cybercrimes" caused by infringement.

In addition, security concerns are not being addressed by the government through the implementation of appropriate legislative rules and procedures (.R Eadie et al.2015). In this case, the legal risk of having BIM details is a great illustration. If owners pay for the architectural design of construction projects, they are entitled to claim ownership of the design papers. When parties other than owners and architects contribute knowledge to BIM, licensing problems can occur (S.Lui et al.). Another potentially very risky issue is deciding who can control information access and take accountability for mistakes (Roa et al,). Stakeholders in the BIM model want sensitive data to be protected, however managing development projects in a technological setting has brought up a variety of security and legal concerns (S.Lui et al.)

1.5.4 Hight Cost Implementation

According to research on the challenges of developing construction robotics technology in Malaysia, one of the barriers to AI technology's broad adoption in the construction industry has been the high cost of implementing it in building projects (M.Y.B Yahya,et al.) The study's conclusions indicate that the cost of deployment outweighs other barriers to new technology adoption in Malaysia's construction industry.

First of all, the building industry may find it difficult to obtain new machinery or innovations (I.D.M. Aripin,2019). New technology is not as easily accessible in the building industry as it is in other sectors due to a lack of innovation.

. Research and development, or R&D, is essential to any business. However, the benefits of R&D are long-term, while the costs are currently incurred. R&D received less attention in the construction sector than in other sectors because of this discrepancy, which is unsuitable for the project-driven business model in which it functions.

Second, maintaining or updating things with AI technology is costly (M.Y.B Yahya,et al.). Additionally, using AI technologies requires a certain amount of expertise. Since the majority of the construction workers on site are unskilled laborers, the organization will need to set aside a specific amount of money for staff training. In order to facilitate the use of AI technology during the construction project period, a corporation may occasionally additionally need to hire specialists, such as technical consultants.

In conclusion, the broad adoption of AI technology in the construction sector is hampered by these two additional expenses for new technologies. Due to the high cost of implementing developing technologies, these investments are only possible for large construction enterprises with strong financial backing.

1.5.5. Lack of Specialists' IT Infrastructure

A significant skill development, particularly sufficient staff training and significant information technology (IT) updates, would be required to implement AI technology in a large organization and industry. One major barrier to expanding the use of AI in architectural engineering and construction (AEC) organizations is a shortage of skilled or qualified personnel (I.D.M. Aripin,2019). As AI develops into a general-purpose technology, numerous AI specialists are needed to take AI programs from conception to execution, and many skilled workers are needed to operate AI-based equipment or computer programming (R.Susskind et al.2022.).

The inability of academic and educational programs to keep up with the rate of innovation and new AI discoveries is the reason for the shortage of AI specialists. aside from formal preparation. Experience in the workplace will be necessary for AI practitioners. Consequently, there aren't enough seasoned AI professionals who are only starting to integrate AI methods into their operations to assume the leadership role that the market demands. Furthermore, the absence of IT infrastructure continues to be a concern for many IT professionals as a barrier to AI in the construction sector (M.Y.B Yahya,et al.). Large volumes of data and extremely quick equipment are needed for training and design models. The expense of deploying AI has increased due to the high cost of high-performance computing systems. The high expense of technology makes most managers reluctant to invest in it (Izabela Hager, 2016).The lack of perceived IT spending investments and a project focus on maximizing return on process investment from individual projects may be the causes of this reluctance to invest in IT (Abd Hamid et al.).

2.0 Materials and Methodology

This research seeks to explore the Role of AI in Transforming Construction Innovation and Enhancing Safety Standards in Ghana. A quantitative research method was employed. This method was deemed necessary because it allows for the use of structured questionnaire surveys, which enable researchers to generalize their findings among the larger population

2.1 Research Design

This study adopts a quantitative research approach to achieve the objectives outlined. By utilizing numerical data to capture the opinions, attitudes, experiences, and behaviors of construction professionals, this approach allows for the systematic analysis of AI's role in transforming construction innovation and enhancing safety standards in Ghana's construction sector.

2.2 Research Method

To gather information that supports the objectives of the study, a structured questionnaire was created. As suggested by Rowley [29], this survey-based approach was used because it is good for capturing frequencies and quantifying things like ideas, attitudes, and experiences on AI's role in the construction sector.

The study's keywords, including "AI," "construction safety," "enforcement," and "productivity," guided the literature review across databases like Google Scholar, ScienceDirect, and JSTOR, informing the questionnaire's development.

2.3 Population and Sampling

The target population for this research includes construction professionals such as project managers, architects, engineers, quantity surveyors, and contractors. Given the challenge of identifying professionals knowledgeable about AI and safety technologies, a combination of purposive and snowball sampling was applied. The purposive sampling technique identified initial respondents who work in large Ghanaian construction firms and have experience with safety and AI technologies. These respondents then referred additional qualified participants, allowing for broader reach.

Of the 180 questionnaires distributed, 164 were retrieved, representing a response rate of 91%, making the data sample robust for analysis.

2.4 Research Instrument

A four-section questionnaire was created, with each section dedicated to a specific research focus:

Section 1: Demographic Information

Collected background information on the respondents, including gender, education level, role in construction, and years of experience.

Section 2 The current state of AI adoption in Ghana's construction industry

Used a 5-point Likert scale (1 = not important to 5 = very important) to assess how respondents view on the current state of AI's adoption in Ghana's construction industry.

Section 3: Impact of AI on Enhancing Construction Safety Standards in Ghana.

Evaluated the level of AI in enhancing safety in construction within the respondents' firms using a Likert scale (1 = not utilized to 5 = highly utilized).

Section 4: Barriers to AI Adoption

Assessed the significance of challenges to AI implementation in Ghana's construction sector, including Lack of skilled workers high implementation costs of AI, resistance to innovation and change, challenges in integrating AI into workflows, rated on a 5-point Likert scale (1 = not significant to 5 = highly significant).

Section 5: Strategies for integrating AI to advance both safety and innovation in the construction industry sector.

Assessed the Strategies for integrating AI to advance both safety and innovation Ghana's construction sector, including Incorporating AI to predict and mitigate safety risks, Adopting AI-driven robotics to streamline processes, Leveraging AI for real-time hazard detection, Using AI to enhance collaborative innovation, Developing training programs for AI adoption. Used a 5-point Likert scale (1 = not important to 5 = very important) to assess how respondents view on the strategies for integrating AI to advance both safety and innovation in Ghana's construction industry.

To make sure the questions were clear and pertinent, the questionnaire was piloted with 20 health and safety professionals, 6 of whom were from academia and 14 of whom were in the construction sector. The questionnaire was finally distributed via Google Forms after feedback indicated that it successfully collected the data needed to meet the study's goals.

2.5 Pilot Study and Reliability Analysis

The pilot study sought to guarantee the validity and reliability of the survey instrument in accordance with Bullen (2021). To assess the internal consistency of replies across sections, Cronbach's alpha was computed. A high Cronbach's alpha value (e.g., $\alpha > 0.8$) would demonstrate a high degree of internal consistency and validate the questionnaire's reliability.

2.6 Data Collection Procedures

Google Forms was used to gather data online in order to guarantee responder confidentiality and participant accessibility from different places. It was also logistically efficient to use online polls because doing in-person interviews on a wide scale is challenging.

2.7 Data Analysis Techniques

The Statistical Package for the Social Sciences (SPSS) program was used to analyse the data in order to produce accurate results. The Likert Scale Questionnaire was the primary tool used to collect data. To improve comprehension and interpretation, the collected data was examined and presented in a variety of ways, including tables, graphs, and pie charts.

3. Results

This chapter presents the outcomes and discussions derived from the field survey conducted subsequent to data collection. The primary data obtained from a diverse range of respondents, including construction professionals such as Architects, Construction Managers, , and Site Engineers, is analysed herein

3.1 Respondents Demographic Profile

This section offers a summary of the group of people who responded to the study and their individual characteristics, which may include their gender, job position, education, length of professional experience, and other significant aspects that might impact their viewpoints and encounters. Moreover, the section may point out any remarkable trends or regularities detected in the data. This data can assist in comprehending the context and history of the study participants, as well as in identifying any possible prejudices or limitations in the data. Furthermore, it can assist in analysing the outcomes and drawing valuable inferences from the research.

The demographic details of the survey participants are presented in Table 3.1 Out of the 164 questionnaires returned, 78 respondents (47.56%) were architects, 26 (15.85%) were construction managers, 42 (25.60%) were engineers, and the remaining 18 (10.97%) were real estate practitioners. This diverse representation across various professional roles provides a broad perspective, contributing valuable insights into the study.

The survey gathered information on respondents' work experience across a range of years. A significant portion, 39.02% (62 individuals), had 5–10 years of experience. Another 18.90% (31 individuals) had 11–15 years of experience, while 27.27% (45 individuals) were early-career professionals with 0–5 years of experience. Finally, 15.85% (26 individuals) had over 15 years of experience. This variety in experience levels brings a well-rounded perspective to the findings, capturing insights from both newer and more experienced professionals

The qualifications of these professionals varied across different levels. A small portion held doctorate degrees (6.7%, or 11 individuals), followed by those with master's degrees, comprising 23.2% (38 individuals). The majority, however, held bachelor's degrees, accounting for 58.5% (69 individuals). Additionally, 28.1% (46 individuals) possessed Higher National Diplomas (HND) in related fields. This range of educational backgrounds adds depth to the study, offering insights from professionals with varying levels of academic training.

Respondents Demographic Profile

Demographic	Frequency	Percentage
Profession		
Architect	78	47.56
Construction Managers	26	15.85
Engineer	42	25.60
Real Estate Practitioners	18	10.97
T0TAL	**164**	**100**
Level of Education		
HND	46	28.04

BSc	69	42.07
MSc/M.Arch	38	23.17
PhD	11	6.67
TOTAL	**164**	**100**
Years of Experience		
0-5	45	27.27
5-10	62	39.02
11-15	31	18.90
Over 15	26	15.85
TOTAL	**164**	**100**

Table 3.1 Summary on respondent's demographic

3.2 The current state of AI adoption in Ghana's construction industry.

According to the ranking of professionals' perceptions regarding the adoption of AI technologies in Ghana's construction sector (see Table 3.1), the most prominent AI applications are as follows: AI in project management (mean score = 4.12, standard deviation = 1.15), which professionals view as critical for enhancing project efficiency and coordination; AI for optimizing resource allocation (mean score = 3.65, standard deviation = 1.21), highlighting its role in reducing waste and improving cost management; AI for general construction tasks (mean score = 3.10, standard deviation = 1.05)emphasizing its adaptability across various workflows. Safety-focused applications include AI integrated into safety monitoring systems (mean score = 2.95, standard deviation = 0.98) and AI used for data analysis in safety (mean score = 3.25, standard deviation = 1.02), reflecting growing interest in leveraging AI to prevent accidents and improve site safety. Lastly, AI-driven robotics and automation (mean score = 2.85, standard deviation = 0.89) indicates emerging potential, signalling the industry's readiness to adopt advanced technological solutions for repetitive and hazardous tasks.

These rankings underscore the growing role of AI in reshaping construction operations in Ghana. The data indicates a strong emphasis on leveraging AI to enhance project management efficiency, optimize resource allocation, and improve safety practices. Specific applications such as AI-driven safety monitoring systems and robotics highlight a targeted approach to addressing safety concerns and operational challenges in the sector.

AI Application	**Mean**	**Standard Deviation**	**t-value**	Statistical Significance	Ranking
AI in project management	4.12	1.15	4.83	Yes	1st
AI for optimizing resource allocation	3.65	1.21	3.00	Yes	2nd
AI for general construction tasks	3.10	1.05	2.67	Yes	3rd
AI integrated into safety monitoring systems	2.95	0.98	2.00	Yes	4th
AI used for data analysis in safety	3.25	1.02	2.94	Yes	5th
AI-driven robotics and automation	2.85	0.89	1.95	Yes	6th

Table 3.2 Current State of AI adoption in Ghana

While the mean scores indicate the perceived prevalence of various AI applications in Ghana's construction sector, a one-sample t-test was conducted to evaluate their statistical significance relative to a hypothesized mean of 3.0. The results, as shown in Table 3.2, reveal that AI applications such as safety monitoring systems, data analysis, and robotics had negative t-values, suggesting that their mean scores were below the hypothesized threshold. Conversely, AI in project management demonstrated a significant t-value of 5.49, surpassing the hypothesized mean, with AI for resource allocation alsoachieving a positive and statistically significant t-value.

The p-values for AI in project management and AI for resource allocation were both below 0.05, affirming their statistical significance. These findings suggest that these two applications are not only more prevalent but also more widely adopted within Ghana's construction processes compared to other AI technologies. This highlights the sector's prioritization of enhancing project efficiency and resource optimization through targeted AI integration.

3.3 Impact of AI on Enhancing Construction Safety Standards in Ghana.

Based on the rankings of professionals' perceptions regarding the impact of AI on the construction industry in Ghana (see Table 3.3), the most positively perceived impacts of AI adoption are as follows: AI's potential to improve safety standards on construction sites (mean score = 4.33, standard deviation

= 0.86), AI's ability to lead to greater efficiency and cost savings in construction projects (mean score = 4.26, standard deviation = 0.91), AI's role in reducing human error and accidents in construction work (mean score = 4.38, standard deviation = 0.79), and AI's contribution to more sustainable construction practices in Ghana (mean score = 4.24, standard deviation = 0.93).

The high mean scores indicate strong agreement among respondents that AI adoption has a significant potential to enhance safety, efficiency, reduce errors, and promote sustainability in construction. These findings highlight a positive outlook on the potential benefits of AI integration within the sector.

Impact of AI	Mean	Standard Deviation	t-value	Statistical Significance	Ranking
Improve Safety standards	4.33	0.86	10.9	Yes	1st
Efficiency and Cost savings	4.26	0.91	9.89	Yes	2nd
Reduce human errors and accidents	4.24	0.79	12.23	No	3rd
Contribute to more sustainable practices	2.39	0.93	8.89	No	4th

Table 3.3 Impact of AI on Enhancing Construction Safety Standards in Ghana

An analysis of professionals' perceptions of AI's impact in Ghana's construction industry was conducted using a one-sample t-test to assess the significance of various AI applications. The test results, detailed in the table, show that most areas had negative t-values, indicating their mean scores fell below the hypothesized mean of 3.5, reflecting a moderate perceived impact. However, the category "AI's potential to significantly improve safety standards" showed a positive t-value of 3.98, as its mean score surpassed the 3.5 threshold.

This category, along with "AI's role in enhancing efficiency and reducing costs," also had p-values under 0.05, confirming their statistical significance. This suggests that professionals strongly perceive AI as impactful in improving safety and operational efficiency within Ghana's construction sector. Meanwhile, other areas, like AI's contribution to reducing human error and fostering sustainability, were viewed as valuable but showed less statistical significance, implying these impacts are acknowledged but are yet to be fully realized in the industry.

3.4 Challenges and barriers to AI implementation within the Ghanaian construction sector.

According to the rankings (Table 3.4) based on professionals' perceptions, the most significant barriers to AI adoption in the Ghanaian construction industry are as follows: lack of skilled workers (mean score (MS) = 3.71, standard deviation (SD) = 1.36), high implementation costs of AI technologies (MS = 3.65, SD = 1.41), resistance to innovation and change (MS = 3.57, SD = 1.44), and challenges in integrating AI into existing workflows (MS = 3.35, SD = 1.65)

Barrier to AI Adoption	Mean	Standard Deviation	t-value	Statistical Significance	Ranking
Lack of skilled workers	3.71	1.36	2.12	Yes	1st
High implementation costs of AI	3.65	1.41	1.84	Yes	2nd
Resistance to innovation and change	3.57	1.44	0.86	Yes	3rd
Challenges in integrating AI into workflows	3.35	1.65	-0.91	No	4th

Table 3.4 Barriers to Adoption

A one-sample t-test was conducted to evaluate the statistical significance of these barriers, using a hypothesized mean of 3.5. The results reveal that the lack of skilled workers ($t = 2.12$, $p < 0.05$) and the high cost of implementing AI ($t = 1.84$, $p < 0.05$) are statistically significant and represent critical challenges. Resistance to innovation and change ($t = 0.86$, $p < 0.05$) was also found to be a significant barrier. However, the difficulty in integrating AI into existing workflows ($t = -0.91$, $p > 0.05$) was not statistically significant, as its mean score fell below the hypothesized threshold, reflecting greater variability in respondents' opinions on this issue.

These findings highlight the pressing need to address key obstacles, particularly the development of skilled labor, the reduction of implementation costs, and the promotion of a culture that embraces innovation. Overcoming these challenges is essential for unlocking the full potential of AI to advance safety and innovation within the Ghanaian construction sector.

3.5 Strategies for integrating AI to advance both safety and innovation in the construction industry sector.

According to the rankings (Table 3.5) based on professionals' perceptions, the most impactful strategies for leveraging AI in Ghana's construction industry are as follows: incorporating AI to predict and mitigate safety risks (mean score (MS) = 4.38, standard deviation (SD) = 0.79), adopting AI-driven robotics to streamline processes (MS = 4.24, SD = 0.93), and leveraging AI for real-time hazard detection (MS = 4.18, SD = 0.87).

Table 3.4 Barriers to Adoption

Strategy	**Mean**	**Standard Deviation**	**t-value**	**Statistical Significance**	**Ranking**
Incorporating AI to predict and mitigate safety risks	4.38	0.79	9.87	Yes	1st
Adopting AI-driven robotics to streamline processes	4.24	0.93	7.65	Yes	2nd
Leveraging AI for real-time hazard detection	4.18	0.87	6.89	Yes	3rd
Using AI to enhance collaborative innovation	4.10	0.85	6.02	Yes	
Developing training programs for AI adoption	4.06	0.88	5.43	No	4th

A one-sample t-test was conducted using a hypothesized mean of 3.5 to evaluate the statistical significance of these strategies. The results indicate that incorporating AI to predict and mitigate safety risks ($t = 10.58$, $p < 0.001$), adopting AI-driven robotics ($t = 7.96$, $p < 0.001$), and leveraging AI for hazard detection ($t = 8.50$, $p < 0.001$) were all statistically significant. These findings highlight a strong consensus on the critical role of AI in addressing safety challenges and advancing innovation within the sector.

The data underscores the growing importance of targeted AI applications in construction, emphasizing a need for continued investment in predictive technologies, automation, and proactive hazard management to drive progress and improve safety standards across the industry.

4. Discussion

4.1 The current state of AI adoption in Ghana's construction industry.

From Table 3.2 , respondents generally indicated that certain AI technologies hold substantial importance for the Ghanaian construction sector. The high mean score for AI in project management (3.87) highlights this application as a priority among professionals, suggesting it plays a key role in improving planning, coordination, and project efficiency. This finding aligns with previous studies underscoring the value of technological integration for optimizing project outcomes. Similarly, AI for resource allocation showed statistical significance, with professionals recognizing its utility in improving resource efficiency—an area critical to sustainable construction practices.

Conversely, lower mean scores for AI applications in safety monitoring, robotics, and general construction tasks (ranging between 1.47 and 2.39) suggest these technologies are less commonly adopted, possibly due to limited infrastructure or high costs. This observation mirrors findings from other studies emphasizing the challenges in adopting advanced technologies where foundational systems and resources may be lacking. Nonetheless, the potential of these technologies to improve safety and operational efficiency aligns with prior research advocating for broader AI implementation to support health and safety management on construction sites.

These results are consistent with studies by Awolushi et al. and Nnaji and Karakhan , which affirm the role of technology in advancing construction procedures and safety practices. Although AI-driven tools like robotics and automated safety systems are less prevalent, this aligns with industry trends where more advanced AI applications typically face initial barriers. As these foundational AI applications gain traction, broader AI integration may follow, supporting improved safety, efficiency, and resource management across Ghana’s construction sector.

4.2 Impact of AI on Enhancing Construction Safety Standards in Ghana.

The data in Table 4 offers insightful perspectives on professionals’ views regarding the impact of AI on Ghana’s construction industry. Among the perceived benefits, AI’s potential to improve safety standards ranked highest with a mean score of 4.33 (standard deviation = 0.86), indicating a strong consensus on the importance of AI for enhancing site safety. This high rating aligns with existing literature, which emphasizes AI’s value in proactively managing construction safety through monitoring systems, hazard detection, and predictive analytics. The statistically significant t-value (10.9) further supports this perception, underscoring safety as a primary focus for AI adoption in the sector.

Closely following, AI’s role in increasing efficiency and achieving cost savings (mean score = 4.26, standard deviation = 0.91) also received high ratings, indicating a shared recognition of AI’s ability to streamline construction processes and reduce resource wastage. This perception is statistically significant, as shown by the t-value (9.89) and p-value under 0.05, suggesting that respondents see AI as an essential tool for optimizing workflow and minimizing operational costs—a finding consistent with global trends where AI has demonstrated significant ROI by automating repetitive tasks and improving resource allocation.

AI’s role in reducing human error and accidents was rated with a mean score of 4.24 (standard deviation = 0.79), slightly below the top-ranked categories, but with a positive t-value, indicating strong support. Although this area showed no statistical significance, it suggests that while professionals acknowledge AI’s potential for improving accuracy and mitigating risk, its implementation in this regard may still be emerging, with limited fully integrated solutions.

Interestingly, AI’s contribution to sustainable construction practices was perceived positively (mean score = 2.39, standard deviation = 0.93), though it ranked lower in terms of perceived impact and was not statistically significant. This suggests that while AI’s role in fostering sustainability is acknowledged, it may be less prominent in current applications within Ghana. This finding is consistent with the gradual progression seen globally, where AI's sustainability potential often requires more foundational integration and industry adaptation to materialize fully.

Overall, the positive mean scores across all categories reflect a promising outlook on AI's impact, especially regarding safety, efficiency, and risk reduction. The statistically significant ratings for safety improvement and cost efficiency reinforce the sector's interest in AI as a means to enhance operational standards and productivity. However, the less significant results in reducing human error and promoting sustainability suggest that these areas may benefit from further development and investment to realize their full potential in Ghana's construction industry. This data indicates that, while there is optimism around AI's transformative capabilities, there is also a need for ongoing infrastructure and skill-building to support broader, effective AI integration.

4.3 Challenges and barriers to AI implementation within the Ghanaian construction sector.

The insights presented in Table 4 shed light on the critical challenges professionals perceive in adopting AI within Ghana's construction industry. The most pressing barrier identified was the lack of skilled workers, which ranked highest with a mean score (MS) of 3.71 and a standard deviation (SD) of 1.36. This finding highlights the workforce gap as a significant impediment to advancing AI adoption. A statistically significant t-value (2.12, $p < 0.05$) confirms the criticality of this issue, underscoring the urgent need for targeted training and education to equip professionals with the necessary technical skills. This aligns with global patterns where the shortage of AI expertise is a common barrier across industries.

Following closely, the high cost of implementing AI technologies also emerged as a key challenge (MS = 3.65, SD = 1.41, $t = 1.84$, $p < 0.05$). The financial burden associated with acquiring and integrating AI tools resonates strongly with respondents, particularly given Ghana's economic context, where many firms operate with constrained budgets. This reinforces the need for innovative financial solutions, such as subsidies, grants, and public-private partnerships, to mitigate cost-related barriers and encourage widespread adoption of AI.

Resistance to innovation and change ranked third (MS = 3.57, SD = 1.44, $t = 0.86$, $p < 0.05$). This reflects cultural and organizational reluctance, which often stems from limited exposure to technology, fear of disruption, or concerns about job displacement. While statistically significant, this challenge underscores the importance of fostering a culture that embraces change through awareness campaigns, leadership advocacy, and pilot initiatives demonstrating the tangible benefits of AI.

The least significant challenge, difficulties in integrating AI into existing workflows (MS = 3.35, SD = 1.65), was not statistically significant ($t = -0.91$, $p > 0.05$). This suggests varied perspectives among respondents, potentially influenced by differences in organizational readiness or resources. While less critical compared to other barriers, integration challenges warrant attention, as they may impede AI's long-term impact. Customized AI tools and strategies tailored to local contexts could address this variability and facilitate smoother adoption.

These findings underscore the multifaceted nature of barriers to AI adoption in Ghana's construction sector. The statistically significant issues of workforce shortages, financial constraints, and resistance to change highlight areas requiring immediate intervention. Simultaneously, addressing integration challenges will be vital for ensuring sustainable and effective implementation. Collectively, these barriers emphasize the need for a comprehensive strategy encompassing skill development, financial support, and cultural transformation to fully realize AI's potential in enhancing safety, efficiency, and innovation within the industry.

4.5 Strategies for integrating AI to advance both safety and innovation in the construction industry sector.

The data in Table X provides a comprehensive evaluation of strategies for integrating AI into Ghana's construction sector, with a focus on advancing safety and innovation. Among the identified strategies, incorporating AI to predict and mitigate safety risks ranked highest, with a mean score (MS) of 4.38 and a standard deviation (SD) of 0.79. This result is statistically significant ($t = 10.58$, $p < 0.001$) and highlights a strong consensus among professionals on the transformative potential of predictive AI technologies. Such systems, by proactively identifying and addressing risks, are seen as critical to improving construction site safety and reducing accidents. This finding aligns with global trends where predictive analytics is pivotal in preempting hazards and minimizing workplace injuries.

Following closely, adopting AI-driven robotics to streamline processes emerged as the second most impactful strategy (MS = 4.24, SD = 0.93, $t = 7.96$, $p < 0.001$). This underscores the recognition of robotics in enhancing operational efficiency by automating repetitive tasks, improving precision, and optimizing resource use. In a sector like construction, where efficiency gains are tightly linked to cost reductions and project timelines, AI-driven robotics hold substantial promise for transforming workflow dynamics.

The third-ranked strategy, leveraging AI for real-time hazard detection, also received significant support (MS = 4.18, SD = 0.87, $t = 8.50$, $p < 0.001$). Real-time hazard detection systems enabled by AI are pivotal in dynamic construction environments, where rapid identification and mitigation of risks are essential. The high mean score reflects the perceived value of these systems in fostering a responsive and safer work culture.

Using AI to enhance collaborative innovation (MS = 4.10, SD = 0.85, $t = 6.02$, $p < 0.001$) and developing training programs for AI adoption (MS = 4.06, SD = 0.88, $t = 5.43$, $p > 0.05$) also scored positively. While the latter was not statistically significant, it points to an acknowledgment of the need to equip professionals with the skills required to navigate AI-integrated workflows. Training initiatives are foundational for addressing the skills gap and ensuring that construction teams are prepared to leverage AI technologies effectively.

These findings collectively emphasize a clear consensus on the importance of targeted AI applications in Ghana's construction sector. The statistically significant results for predictive safety technologies, robotics, and hazard detection highlight areas where AI can make the most immediate impact. However, the relatively lower emphasis on training programs suggests a need for greater advocacy and investment in workforce development to maximize the sector's AI readiness.

Overall, the data underscores a promising outlook for AI integration, with professionals recognizing its potential to redefine safety standards, drive efficiency, and promote innovative practices in the construction industry. To fully capitalize on these opportunities, sustained efforts in policy, funding, and training will be critical for embedding AI into the core of construction practices in Ghana.

5. Conclusion

The findings of this research highlight the transformative potential of artificial intelligence (AI) in advancing Ghana's construction industry, particularly in enhancing safety, operational efficiency, and innovation. The adoption of AI in project management and resource allocation has been recognized as pivotal, underscoring its role in optimizing workflows and reducing waste. While safety-focused applications such as AI-driven monitoring systems and hazard prediction tools are gaining traction, the industry remains in the early stages of integrating these technologies into broader construction processes

AI's ability to improve safety standards, reduce human error, and foster sustainable practices has been widely acknowledged, with significant support for predictive AI technologies and robotics to address safety risks and streamline processes. However, challenges persist, including the lack of skilled workers, high implementation costs, and resistance to innovation. Addressing these barriers through targeted strategies—such as training initiatives, cost-reduction measures, and fostering a culture of innovation—will be essential for unlocking AI's full potential.

To capitalize on the benefits of AI, stakeholders in Ghana's construction sector must prioritize investment in technology, develop comprehensive training programs, and establish collaborative frameworks that integrate AI into existing workflows. These efforts will not only enhance safety and efficiency but also position Ghana's construction industry as a leader in adopting innovative technologies to drive sustainable development.

this study not only underscores the transformative potential of AI in enhancing construction safety and efficiency in Ghana but also offers a blueprint for developing economies to harness emerging technologies. By addressing key challenges, stakeholders can catalyze industry-wide innovation, setting the stage for more sustainable and resilient construction practices globally.

References

Aasonaa, D. N. (2023). Role of the construction project team in health and safety management: a study of construction projects in the Wa Municipality of Ghana. International Journal of Occupational Safety and Health, 13(2), 214–222. https://doi.org/10.3126/ijosh.v13i2.37445

Abd Hamid, A.B., & Embi, M.R. (2016). Review on application of Building Information Modelling in interior design industry. In MATEC Web of Conferences (Vol. 66, p. 00003). EDP Sciences.

Adzivor, E. K., Emuze, F., & Das, D. K. (2022). Indicators for safety culture in SME construction firms: a Delphi study in Ghana. Journal of Financial Management of Property and Construction, 28(3), 293–316. https://doi.org/10.1108/jfmpc-04-2022-0020

Agyekum, K., Pittri, H., Botchway, E.A., Amudjie, J., Kumah, V.M.A., Kotei-Martin, J.N., & Oduro, R.A. (2022). Exploring the current technologies essential for health and safety in the Ghanaian construction industry. Merits, 2(4), 314–330. https://doi.org/10.3390/merits2040022

Barker, T., Bashmakov I., Alharthi, A., Amann, M., Cifuentes, L., Drexhage, J., Duan, M., Edenhofer, O., Flannery, B., Grubb, M., Hoogwijk, M., Ibitoye, F.I., Jepma, C.J., Pizer, W.A., & Yamaji, K. (2007). Mitigation from a cross-sectoral perspective. Proceedings of the Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Balaguer, C. Nowadays trends in robotics and automation in construction industry: Transition from hard to soft robotics. In Proceedings of the International Symposium on Automation and Robotics in Construction, New Orleans, LA, USA.

Blanco, J.L., Fuchs, S., Parsons, M., & Ribeirinho, M.J. (2018). Artificial intelligence: Construction technology’s next frontier. The Building Economist.

Boadu, E.F., Wang, C., & Sunindijo, R.Y. (2020). Characteristics of the construction industry in developing countries and its implications for health and safety: an exploratory study in Ghana. International Journal of Environmental Research and Public Health, 17(11), 4110. https://doi.org/10.3390/ijerph17114110

Chien C.D.-P.S., Huh W., Jang Y., & Morrison J. (2020). Artificial intelligence in manufacturing and logistics systems: algorithms, applications, and case studies. Int. J. Prod. Res., 58(9), 2730–2731.

Chui M.S.L., Francisco S.L.McKinsey (2017). Artificial Intelligence the Next Digital frontier? McKinsey and Company Global Institute.

Eadie R., McLernon T., & Patton A.(2015). An investigation into the legal issues relating to building information modelling (BIM). In RICS Cobra Aubea.

Giang D.T., & Pheng L.S.(2011). Role of construction in economic development: review of key concepts in the past 40 years.Habitat Int.

Hatami M., Paneru S., & Flood I.(2022). Applicability of Artificial Intelligence (AI) Methods to Construction Manufacturing: A Literature Review.Construction Research Congress 2022.

Javed A.; Pan W.; Chen L.; Zhan W.(2018). A systemic exploration of drivers for and constraints on construction productivity enhancement.Built Environ.Proj.Asset Manag.

Liu S., Xie B., Tivendale L., & Liu C.(2015). The driving force of government in promoting BIM implementation.J.Mgmt.& Sustainability.

Maskuriy R.; Selamat A.; Ali K.N.(2019). Industry 4.O for the construction industry—how ready is the industry?.Applied Sciences.

Mohammadpour A.; Karan E.; Asadi S.(2018). Artificial intelligence techniques to support design and construction.In Proceedings of the International Symposium on Automation and Robotics in Construction ISARC.

Mustapha Z.(2016). Revised health and safety compliance model for the Ghanaian construction industry.International Journal of Engineering Science and Technology.

Oesterreich T.D.and Teuteberg F.(2016). Understanding the implications of digitisation and automation in the context of Industry 4.O: A triangulation approach.Computers in Industry.

.Phinias R.N.(2023). Benefits and challenges relating to the implementation of health and safety leading indicators in the construction industry: A systematic review.Safety Science.

.Rao T.; Gaddam A.; Kurni M.; Saritha K.(2021). Reliance on artificial intelligence,machine learning and deep learning in the Era of industry 4.O.In Smart Healthcare System Design: Security Privacy Aspects.Wiley.

.Regona M.; Yigitcanlar T.; Xia B.; Li R.Y.M.(2022). Opportunities and adoption challenges of AI in the construction industry: A PRISMA review.Journal of open innovation: technology market complexity.

.Shukla A.K.; Janmaijaya M.; Abraham A.; Muhuri P.K.(2019). Engineering applications of artificial intelligence: A bibliometric analysis of 30 years (1988–2018).Eng.Appl.Artif.Intell.

.Simpson K.& Sam A.(2019). Strategies for health and safety management in Ghana.Journal of Engineering Design Technology.

.Williams J.; Fugar F.; Adinyira E.(2019). Assessment of health and safety culture maturity in the construction industry in developing economies.Journal of Engineering Design Technology.

.Yahya M.Y.B.; Hui Y.L.; Yassin A.B.M; Omar R; anak Robin R.O; Kasim N.(2019). The challenges of the implementation of construction robotics technologies in the construction.In MATEC Web of Conferences.

.Zhou K.; Liu T.; Zhou L.(2015) Industry 4.O: Towards future industrial opportunities and challenges.In 2015 12th International conference on fuzzy systems knowledge discovery.

.Zhou P.D(2014). Uncover the Gorgeous Coat of Industrial 4.O Programmable Controller Factory Automation.

.Susskind R.and Susskind D(2022). The future professions: How technology will transform work human experts.Oxford University Press.