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| RESEARCH ARTICLE

Evaluation of the Readiness of the Ghanaian Construction Industry for the Integration of Construction 4.0 Technologies and Factors Influencing the Readiness

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| ABSTRACT
This study evaluates the readiness of the Ghanaian construction industry for the integration of Construction 4.0 technologies and factors influencing the readiness. The population for this study comprised stakeholders involved in large-scale infrastructure projects in Ghana. The research adopted a sample size of 120. The target was 30 participants from each group of the population, namely government agencies, construction firms, technology providers, and consultants. Data collection involved both structured and semi-structured questionnaires administered via Google Forms. Quantitative data was analysed statistically, while qualitative data underwent thematic analysis. The findings regarding industry readiness revealed a mixed picture. While enthusiasm for C4.0 exists, challenges such as a lack of skilled labour, high initial costs, and limited awareness hinder widespread adoption. Training programs and collaboration with technology providers emerged as crucial factors in overcoming these barriers. The study concludes by recommending that stakeholders, including government and industry leaders, should develop a strategic framework to enhance the technological readiness of the construction sector. This could include initiatives such as workforce training programs, investment in digital infrastructure, and creating incentives for technology adoption. Future research should focus on longitudinal studies to assess the long-term impact of C4.0 technologies on project outcomes, including key performance indicators such as cost savings, quality improvements, and safety metrics.

| KEYWORDS

Industry 4.0, Augmented Reality, Internet of Services, Construction 4.0, Cyber-Physical Systems.

| ARTICLE INFORMATION

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1. Introduction

The construction industry in Ghana, like in many other developing economies, produces complex physical infrastructure both for public and private clients. The industry is also a significant driver of economic growth and development. Throughout the country, major regional development projects implemented by the government - including the building of new cities, highways, bridges, airports, and industrial parks for manufacturing, agro-processing, and other industrial activities - rely upon the country's rapidly growing construction industry. Despite the importance of the construction industry to the Ghanaian economy, it has received growing criticism from both government officials and the general public for failing to emerge from its traditional position as one of the lowest-performing sectors of the United Nations Development Program. Ghana, like many of its African peers and developing economies, still struggles to manage continuous development in the pipeline of infrastructure programs and projects. (Owoo & Lambon-Quayefio, 2020; Frimpong et al., 2020; Agyekum et al., 2022).

Master Plan Studies, reports from the Ministry of Roads and Highways, the Ministry of Works and Housing, and the Ghana Investment Promotion Centre (GIPC), as well as "Vision 2020", "Better Ghana", and other institutional and national development documents suggest that the construction industry is yet to fully contribute to the sustainable development of the country. The outlook into the 21st century reveals that population growth, urban expansion, and government efforts to stimulate growth in the industrial and service sectors, enhance the country's ability to compete internationally and improve the living standards must go hand in hand with an efficient and properly managed construction industry. (Owoo & Lambon-Quayefio, 2020) (Li et al., 2020).

The construction industry in Ghana has challenges in project delivery, efficiency, and quality, particularly in the context of large-scale infrastructure projects. Ghana's construction practices remain restricted despite the global evolution towards Construction 4.0, which influences advanced technologies such as the Internet of Things (IoT), Building Information Modeling (BIM), robotics, and automation. The country's infrastructure development and economic growth are being hindered by this lack of effective integration, which is resulting in persistent issues such as project delays, budget overruns, and poor-quality outcomes. To add to that, there is an inadequate understanding of the specific opportunities that Construction 4.0 technologies could offer in addressing these challenges, including their potential to improve project delivery timelines, enhance operational efficiency, and ensure higher quality standards. Likewise, there is a largely low exploitation of the readiness of the Ghanaian construction industry to embrace these advanced technologies. Factors such as workforce skills, existing infrastructure, and regulatory frameworks have not been adequately assessed, creating uncertainty around the industry's capabilities to embrace this technological shift.

The study can serve as a catalyst for technological advancement in the Ghanaian construction industry by identifying opportunities for innovation and the integration of cutting-edge technologies. Promoting the adoption of Construction 4.0 tools like BIM, IoT, robotics, and AI can help position Ghana as a leader in modern construction practices. Understanding the opportunities related to Construction 4.0 technologies can help Ghanaian construction firms enhance their competitiveness in the global market. By leveraging advanced technologies and best practices, companies can differentiate themselves, attract investment, and participate in international projects more effectively.

2. Literature Review

2.1 Overview of large-scale infrastructure projects in Ghana

After the adoption of economic reforms and structural adjustment programs in the 1980s, there has been a dramatic upsurge in the realization of large-scale infrastructure projects in Africa. (Bawa and Ateku2020) This trend can be observed in almost all economies on the continent, particularly in the power, transport, and telecommunication sectors. Infrastructure development has been favoured as a means of enhancing the productive capacity in sub-Saharan Africa (SSA), and more technically, one of the ways by which fast economic growth could be realized in the late starters (Appiah et al., 2022). In 2011, the World Bank reported that Ghana's infrastructure development is steadily promoting greater connectivity and industrial agglomeration across the country—with historically underserved areas in the north and the central region of the country also making steps forward. (Cobbinah et al., 2020)

According to the World Bank in 2015, infrastructure investments play a vital role in achieving resilient growth and ensuring the inclusivity of Ghana's development. As a developing country, agriculture accounts for a high proportion of employment (53.53% in 2019 Q1), followed by the service sector (29.48%), while the industry sector accounts for only 17.03%. The low degree of Ghana's industrialization has become an economic structural constraint limiting the country's further development. Gao et al. (2021) indicated that infrastructure development can increase economic connectivity across the continent by connecting greater economic trade and collaboration. In the long-term, transport infrastructure investments will reduce regional inequalities more effectively to achieve fast economic growth, increased connectivity, and greater industrial agglomeration.

The Ghanaian construction industry has historically been influenced by the practices and systems inherited from the country's former colonial administrators. These systems, which may not align with the local culture, administrative structures, and authority structures, can present barriers to the adoption of new technologies and practices (Boadu et al., 2020).

Additionally, the industry is often described as unfriendly and unkind to the natural environment, with significant concerns about the industry's impact on the environment (Ametepey et al., 2015).

2.2 *Advanced technological innovations in the fourth industrial revolution*

2.2.1 Robotics

According to Srivastava et al.2022, robots are autonomous mechanical systems that can perform tasks without human intervention. Robotic applications in construction. Robots can perform many tasks in the construction industry. For example, a multi-axle robot is used for assembling precast concrete elements; common industrial robots are used for concrete in the construction industry, and robots are used for building structural elements and connecting structural components. Robots are used to build components or structures.

2.2.2 Construction Automation

According to Taplin, mechatronics, electronic control systems, telecommunication applications, and wireless communication technology are based on robotics, GPS, laser, optics, LosCube, software toolkits of GPS positioning systems, interactive design and planning CAD or AR applications, experts with AI and software tools developed and realized for modeling and product management. (Seidu et al.2023)

2.2.3 Artificial Intelligence

Artificial intelligence deals with the design and development of algorithms for autonomous decision-making, learning, and problem-solving, including symbolic methods, statistical methods, computational intelligence, and machine learning predictors that support and manage the machine data and patterns, resulting in optimal construction processes and the entire life cycle of the building. AI is often used in drones, cameras, robots, sensors, and reality modeling technology in a Building Information Model. (Maqbool et al.2023)

2.2.4 Digital twin

The concept of the "digital twin" is increasingly popular for capturing real-time activities and supporting predictive intelligence in decision-making. This approach allows for the virtual reproduction of a construction site across different geographical regions using network technologies. Users can create and test hypotheses before actual implementation, providing unprecedented data and insights into work sites. This capability enables the identification of trends and anomalies that can inform the next generation of policies for hazardous work environments and management practices. However, like many technologies discussed in this work, the adoption of the digital twin concept in the construction industry faces challenges. One major issue is determining how digital twins should be utilized in such dynamic, real-time environments. Additionally, the format of data presentation and visualization for users poses another significant challenge (TURNER et al., 2021).

2.3 Empirical review

Construction 4.0 technologies are being deployed more frequently in the infrastructure sector to address problems of low productivity, waste during construction and maintenance procedures, safety incidents, and low investment levels. The empirical research on how Construction 4.0 technologies are being integrated, deployed, and utilized in the Ghanaian context is limited, more specifically in the large-scale infrastructure subsector (Kissi et al., 2023).

2.3.1 Benefits of construction 4.0 technologies

The conceptual review of the existing literature on the construction processes, procedures, and systems facilitated the identification of seven primary implementation challenges and six main opportunities for the deployment of relevant Construction 4.0 technologies in Ghanaian large-scale infrastructure projects. These are then synthesized to create a more detailed reflection on the current evidence base, identifying key areas for future research directions to stimulate the deployment, integration, and utilization of these identified technologies (Akomea-Frimpong et al., 2023).

During the last decade, numerous studies have elaborated on the elements of digital construction technologies, such as building information modeling (BIM), IoT, AR, VR, drones, big data technology, the mobile technology framework, blockchain, the use of robots and 3D printing, and how these technologies can be employed to advance the construction sector. Previous works have also underscored the various applications of these technologies on construction projects (Forcael et al., 2020).

The review of the literature showed that the construction has benefited from many applications of these advanced techniques. The synthesis suggests that digitization can restrain the issues in material delays, rework, waste, and safety. Moreover, the digital technologies highlighted above are useful tools for enhancing efficiency and quality in the construction sector. It is essential to evaluate, explore, and understand the underlying factors hindering challenges and benefits related to digitizing construction processes in large-scale infrastructure projects, kicked off with the project frontline stakeholders (Ravald, 2021). Modern methods of construction, like prefabrication, additive manufacturing, and on-site assembly, will improve the speed of construction. With real-time access to field data, any potential delays can be avoided, resulting in time savings.

The use of industrialized construction, supported by digital technologies, BIM, and CDE, can help reduce inefficiencies and waste. Robotics and automation can result in a reduction in direct costs. Real-time incentives for project teams to collaborate and innovate.

Cooper, 2018 the Construction 4.0 framework may provide the right mix of enablers to allow the innovation mindset to take root in the industry. Through an integration of the physical and digital layers, it is likely that this innovation will lead to integrated solutions that will strike at the heart of horizontal, vertical, and longitudinal fragmentation that currently dominates the industry.

The construction industry suffers from an image problem caused by several factors. It is well known for its harsh working environment and its low level of automation and digitization. The digital and physical technologies of Construction 4.0 can improve the image of the industry by transforming the work, the worker, and the workplace and making it more attractive for recruitment and retention of talent (Farmer, 2016; Oesterreich and Teuteberg, 2016). In addition, Construction 4.0 enhances site safety. Augmented Reality/Virtual Reality (AR/VR) based training, wearable technologies, IoT-based connectivity of objects, things, and people, and image and video processing can enhance safety.

The horizontal and vertical integration resulting from the adoption of the Construction 4.0 framework allows the monitoring and control of the design and production processes, thereby improving the quality of construction. With real-time monitoring, automated site data collection, image processing, AI, and analytics tools, the time and cost predictability of ongoing projects can be improved. The availability of large volumes of historical data and information can help set benchmarks for early time and cost prediction for new projects, thereby allowing longitudinal integration (Anil Sawhney et al., 2020).

The use of cloud-based project management tools, such as Blockchain, a central repository of information and real-time data access, enhances trust among the project team members and enhances communication, coordination, and collaboration. With this, with the reduction in tedious and repetitive tasks, the project team focuses on creating value and focusing on what matters most to the customer, which brings about customer and end-user satisfaction. (Anil Sawhney et al., 2020)

2.3.2 Challenges and barriers to the integration of construction 4.0 in Ghana

The implementation of Construction 4.0 technologies in Ghana's large-scale infrastructure projects faces several key barriers:

A lack of demand for sustainable buildings, limited strategies to promote sustainable construction, higher initial costs, a lack of public awareness, and a lack of government support have been identified as significant barriers to the adoption of sustainable construction practices in Ghana (Djokoto et al., 2014).

These barriers may also extend to the integration of Construction 4.0 technologies, as they require significant upfront investment and a shift in the industry's mindset towards sustainability and innovation.

These barriers may also extend to the integration of Construction 4.0 technologies, as they require significant upfront investment and a shift in the industry's mindset towards sustainability and innovation. These obstacles can hinder not only the adoption of new technologies but also the overall growth and competitiveness of the construction sector. The reluctance to embrace digital transformation often stems from a fear of disrupting established processes and a lack of understanding of the long-term benefits that such changes can bring. Furthermore, the traditional approach to project delivery, which has historically prioritized cost and time over value, may need re-evaluation in the context of a rapidly evolving technological landscape. (Anil Sawhney et al., 2020)

To successfully navigate these challenges, stakeholders must be willing to invest in training and development, ensuring that the workforce is equipped with the necessary skills to operate advanced tools and systems. Collaborative partnerships between technology providers, contractors, and clients can foster an environment that encourages innovation, allowing for the sharing of resources, expertise, and best practices.

Moreover, the integration of Construction 4.0 technologies—such as Building Information Modeling (BIM), the Internet of Things (IoT), and autonomous construction machinery—can lead to improved efficiency, reduced waste, and enhanced project outcomes when implemented thoughtfully. As the industry shifts towards a more sustainable model, the emphasis on circular economy principles and eco-friendly practices will further drive the need for these advanced technologies (Anil Sawhney et al., 2020).

Ultimately, embracing this shift may require a cultural transformation within organizations, prioritizing innovation and sustainability as core values that align with the global push toward responsible construction practices. By fostering a proactive approach to change, the construction industry can capitalize on the opportunities presented by Construction 4.0, positioning itself for a sustainable future that benefits not only businesses but also the wider community and the environment.

3. Methodology

3.1 Research philosophy

Concerning this research, the researcher has adopted the pragmatic philosophy, which will enable us and any stakeholder in the construction industry in Ghana to have first-hand information on the practical implications of our findings.

3.2 Research design

A survey study was deemed appropriate for this research for three reasons: Survey research involves data collection from construction professionals, generalizing the result of the study to envisage the attitude of the population of interest. In that same manner, survey questionnaires were designed to draw information from the population of interest in a systematic and impartial manner; the questionnaires allowed statistical analysis of data and generalisation of the results to a larger population.

3.3 Sample and sampling technique

This study adopted a combination of purposive and stratified sampling techniques. The method of purposive sampling was used to develop the research sample under discussion. According to this method, which belongs to non-probability sampling techniques, sample members are selected based on their knowledge, relationships, and expertise regarding a research subject (Freedman et al., 2007). According to Parker et al. (2019), purposive sampling is closely associated with qualitative research, aiming to gather information about a population by observing a small portion of it. To select a sample, all sampling units must be compiled to create an accurate sample frame, from which the sample size is determined. An initial survey was conducted to select participants from the construction industry, including individuals from academia and operational construction firms in Ghana. In the current study, the sample members who were selected had a special relationship with the phenomenon under investigation, sufficient and relevant work experience in the field of large-scale construction projects, active involvement in several construction projects and partnerships, as well as proven research background and an understanding of raw data concerning construction.

Stratified sampling is a probability sampling method that involves dividing the population into distinct, non-overlapping groups, known as strata, based on specific characteristics like age, income level, or education. This approach ensures that each subgroup is proportionately represented in the sample, leading to more accurate and reliable insights when examining the overall population. Stratified sampling is particularly advantageous when the objective is to examine specific characteristics across different groups within a diverse population. This method effectively prevents the overrepresentation or underrepresentation of certain traits, a common issue that can arise with simple random sampling (Bisht, 2024).

According to Creswell, J. W., & Creswell, J. D. (2017), in qualitative research, it is generally considered sufficient to have a sample size ranging from 5 to 30 participants. For quantitative research, a minimum sample size of 30 is frequently recommended to facilitate the assumption of a normal distribution. This research has adopted a sample size of 120. The target is 30 participants from each group of the population namely: government agencies, construction firms, technology providers, and consultants.

3.4 Data collection

3.4.1 Interviews

In-depth interviews were used for this research. In-depth interviews are personal and unstructured interviews whose aim is to identify participant's emotions, feelings, and opinions regarding a particular research subject. The main advantage of personal interviews is that they involve personal and direct contact between interviewers and interviewees and eliminate non-response rates, but interviewers need to have developed the necessary skills to successfully carry out an interview (Fisher, 2005; Wilson, 2003). As far as data collection tools were concerned, the research involved the use of a semi-structured questionnaire, which was used as an interview guide for the researcher. Some questions were prepared so that the researcher could guide the interview toward the satisfaction of research objectives, but additional questions were encountered during the interviews.

3.4.2 Surveys

The effectiveness of surveys largely depends on the sampling techniques used to select participants. Probability sampling methods, such as random sampling, ensure that every individual has a known chance of being included, enhancing the representativeness of the sample. Conversely, non-probability sampling methods, like purposive sampling, may introduce bias but can be useful in specific contexts. While surveys offer advantages such as cost-effectiveness and the ability to reach a large audience, they also have limitations, including potential response bias and the risk of misinterpretation of questions. Overall, when designed and executed thoughtfully, surveys can provide valuable data that inform decision-making and contribute to research across various fields (Lohr, 2010; Leedy & Ormrod, 2018).

3.5 Data analysis

3.5.1 Statistical analysis for quantitative data

For our research, we have chosen to use descriptive statistics, which only summarise the information within a data set without concluding its contents. For example, if a company or stakeholder in the construction sector in Ghana gave us a book of its expenses and we summarised the percentage of money it spent on different categories of items, then we would be performing a form of descriptive statistics. When performing descriptive statistics, data visualisation is used to present information in graphs, tables, and charts to convey it to others in an understandable format. Typically, leaders in a company or organisation will use this data to guide their decision-making.

3.5.2 Thematic analysis for qualitative data

Our analyses have also followed the recommended various approaches to conducting thematic analysis, which are familiarisation, coding, generating themes, reviewing themes, defining and naming themes, and writing up. Following this process helped us to avoid confirmation bias when formulating our analysis.

4. Findings and Analysis

4.1 Readiness of the Ghanaian Construction Industry

This section presents the findings from the study conducted with 121 respondents regarding the readiness of the Ghanaian construction industry to adopt Construction 4.0 technologies. The analysis focuses on the responses to the survey questions, providing insights into perceptions of readiness, technological capabilities, perceived challenges, and factors that may facilitate or inhibit the adoption of Construction 4.0 technologies.

4.1.1. Descriptive Statistics

4.1.1.1 Readiness to Adopt Construction 4.0 Technologies

Respondents were asked if they believe the Ghanaian construction industry is ready to adopt Construction 4.0 technologies. The results are as follows:

- **Yes Responses**: Half of the respondents (60 out of 121) answered "Yes," indicating a strong positive sentiment or agreement with the question posed. This represents **50%** of the total responses.

- **No Responses**: A quarter of the respondents (30) expressed disagreement, accounting for **25%** of the total. This suggests a notable minority that does not support the statement.

- **Unsure Responses**: An equal proportion (31 respondents) indicated "Unsure," also representing **25%**. This reflects a significant level of uncertainty among respondents, which may indicate a need for further information or clarification on the topic.

Half of the respondents (50%) believe the industry is ready to adopt Construction 4.0 technologies, while 25% are unsure, indicating a mix of optimism and uncertainty regarding industry readiness.

4.1.1.2 Current Technological Capabilities

The assessment of organizations' current technological capabilities reveals a somewhat mixed picture. Participants were asked to rate their organization’s current technological capabilities on a scale of 1 to 5 (1 = Very Low, 5 = Very High). While the mean score of 3.1 (SD = 1.1) suggests a rating slightly above the midpoint of the 1-5 scale, the frequency distribution indicates a relatively broad spread of opinions. A significant portion (59 respondents, or 49%) rated their technological capabilities as either "medium" (35 respondents, 29%) or "high" (24 respondents, 20%). However, a substantial number (40 respondents, or 33%) rated their capabilities as "low" or "very low," indicating a considerable gap in technological preparedness within the organizations surveyed. A smaller but notable portion (17 respondents, or 14%) rated capabilities as "very high." This suggests that while some organizations are well-equipped technologically, a significant proportion of them require improvement in their technological capabilities.

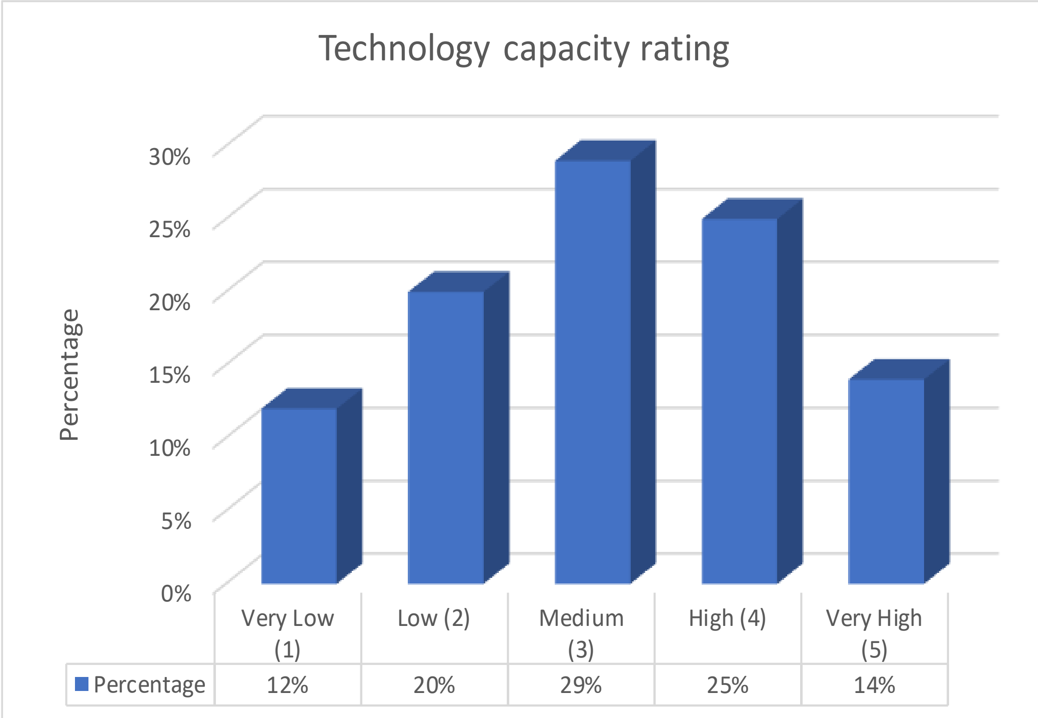

Fig. 1. Current Technological Capabilities

4.1.1.3 Challenges Faced in Adopting Construction 4.0 Technologies

The survey reveals several key challenges hindering the adoption of Construction 4.0 technologies. The most prevalent obstacles, reported by over half of the respondents, are the "lack of awareness or understanding of technologies" (63%) and the "lack of skilled workforce" (58%). These findings highlight a critical need for training and education initiatives to bridge the knowledge gap and develop the necessary expertise. High initial investment costs also pose a significant barrier (52%), suggesting that financial constraints may be a major factor limiting adoption. Resistance to change among staff (46%) and inadequate technological infrastructure (40%) represent further substantial hurdles, indicating the need for effective change management strategies and investment in infrastructure upgrades. While regulatory hurdles (35%) were identified as a factor, they appear to be a less significant challenge compared to the others mentioned. The responses demonstrate that successful adoption of Construction 4.0 technologies requires a multi-faceted approach addressing financial, educational, and cultural aspects within organizations. A bar chart effectively visualizes the relative importance of each challenge.

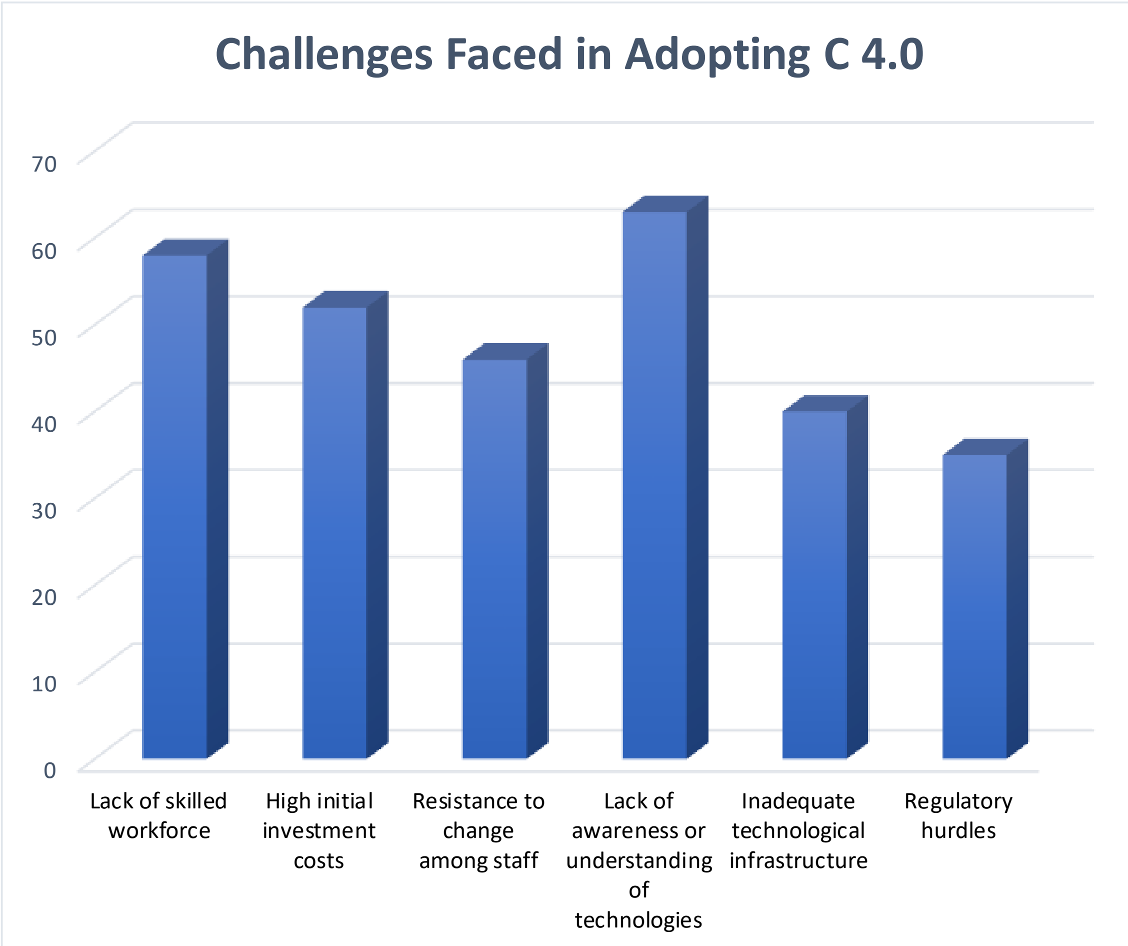

Fig. 2. Challenges Faced in Adopting Construction 4.0 Technologies

4.1.1.4 Perceived Barriers to Adoption of Construction 4.0 Technologies

Table. 1. Factors that would facilitate or inhibit your organization's adoption of Construction 4.0 technologies

Barriers	Mean Rating	RII	Rank
Limited Infrastructure	3.91	0.71	1
Lack of Skilled Workforce	3.63	0.66	3
Data Security and Privacy Concerns	3.61	0.66	4
Cultural and Social Factors	3.73	0.68	2
Lack of Awareness and Education	3.71	0.68	2
Resistance to Change	3.59	0.65	5
Limited Access to Funding	3.56	0.65	6
Environmental and Geographic Challenges	3.63	0.66	4
Non-Uniform Industry Structure	3.58	0.65	6
Short-Term Focus	3.58	0.65	6
High Initial Costs	3.49	0.63	7
Regulatory and Legal Challenges	3.43	0.61	8
Lack of Collaboration	3.67	0.67	3

Limited Infrastructure has the highest mean rating of **3.91** and an RII of **0.71**, indicating it is perceived as the most significant barrier to the adoption of Construction 4.0 technologies. **Lack of Skilled Workforce** and **Data Security and Privacy Concerns** both have RII values of **0.66**, indicating they are also significant barriers. **Regulatory and Legal Challenges** have the lowest RII of **0.61**, suggesting it is perceived as a lesser barrier compared to others.

4.1.1.5 Suggested Strategies for Enhancing Readiness

Respondents provided various suggestions for strategies to enhance the readiness of the Ghanaian construction industry for Construction 4.0 technologies. Common themes included:

- **Training and Development Programs:** Focus on improving workforce skills and knowledge related to new technologies.
- **Investment in Technological Infrastructure:** Encouraging investments to upgrade existing systems and introduce new technologies.
- **Regulatory Support:** Advocating for supportive regulatory frameworks that foster innovation and technology adoption.
- **Increased Collaboration:** Promoting partnerships between stakeholders, including government, educational institutions, and construction firms, to share knowledge and resources.

4.4.2. Correlation Analysis

Next, we will conduct a correlation analysis to understand the relationships between the current technological capabilities, the challenges faced, and the facilitating factors for technology adoption.

Table 2: Correlation matrix for the evaluation of Ghana's readiness for C4.0

Factors	Current Tech Capabilities	Training & Development	Government Incentives	Access to Funding	Collaboration
Current Technological Capabilities	1.00	0.54**	0.42**	0.38**	0.57**
Lack of Skilled Workforce	-0.50**	-0.38*	-0.27	-0.22	-0.31
High Initial Costs	-0.40**	-0.29	-0.15	-0.18	-0.28*
Resistance to Change	-0.44**	-0.36*	-0.25	-0.20	-0.35*

(*$p < 0.05$, **$p < 0.01$)

The correlation analysis reveals significant relationships between current technological capabilities and several factors influencing the adoption of Construction 4.0 technologies. Current technological capabilities show strong positive correlations with both "Training & Development" ($r = 0.54$, $p < 0.01$) and "Collaboration" ($r = 0.57$, $p < 0.01$), suggesting that organizations with higher technological capabilities tend to invest more in training and engage more in collaborative efforts. A moderate positive correlation is also observed with "Access to Funding" ($r = 0.38$, $p < 0.01$) and "Government Incentives" ($r = 0.42$, $p < 0.01$), indicating a link between better technological preparedness and access to resources.

Conversely, the challenges associated with technology adoption show negative correlations with current technological capabilities. "Lack of Skilled Workforce," "High Initial Costs," and "Resistance to Change" all exhibit statistically significant negative correlations ($p < 0.01$ or $p < 0.05$), implying that organizations with stronger current technological capabilities experience fewer difficulties with these issues. The strongest negative correlations are between current technological capabilities and "Resistance to Change" ($r = -0.44$, $p < 0.01$) and "Lack of Skilled Workforce" ($r = -0.50$, $p < 0.01$). This suggests that improved technological capabilities may help mitigate resistance to change and the shortage of skilled labor. In essence, the analysis points to a virtuous cycle where enhanced technological capabilities facilitate training, collaboration, and resource acquisition while simultaneously mitigating several key challenges to technology adoption.

5. Conclusion

The study concluded that **a** lack of skilled workforce and high initial costs were significant barriers impacting readiness. A strong percentage (63%) indicated a lack of awareness of the technologies, which suggests potential for educational initiatives. Training and development programs and collaboration with technology providers showed the strongest positive correlations with current technological capabilities. Government incentives were less significant but still had a positive impact on readiness. The analysis reveals a mixed level of readiness within the Ghanaian construction industry. While there is enthusiasm for adopting Construction 4.0 technologies, challenges such as limited technical expertise, inadequate infrastructure, and resistance to change pose barriers to effective integration.

The study recommends that Stakeholders, including government and industry leaders, should develop a strategic framework to enhance the technological readiness of the construction sector. This could include initiatives such as workforce training programs, investment in digital infrastructure, and creating incentives for technology adoption.

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