A Systematic Literature Review of Influencing Factors and Strategies of Artificial Intelligence Adoption in the Construction Industry

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Abstract. The construction industry has seen an increase in Artificial Intelligence (AI) in recent years, a paradigm shift in many industries. It puts under pressure for technological advancement. Therefore, AI is under great attention in the construction industry as a new strategic paver. This paper adopts a systematic literature review (SLR) approach and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to observe and understand the influencing factors and strategies for AI adoption. The SLR for AI-related research carried out between 2010 and 2020. Data was collected from ASCE Journals, Emerald Insight, Elsevier ScienceDirect, Engineering Village, Google Scholar, ICE virtual library, IOPscience, IEEE Xplore, ScienceDirect, Scopus, SpringerLink and Taylor & Francis. The paper identifies and classifies the new developments in AI research, making its implementation and adoption a reality in the construction industry. This review has the potential for construction industry stakeholders, especially those in developing countries, to utilise the accumulated evidence from selected systematic reviews to enable the usage of AI for infrastructure development.

1. Introduction
The construction industry of countries plays a vital role in growing the economy [1]. More significantly in developing countries. It contributes to job creation, infrastructure development, and GDP growth [2]. However, it is lagging when it comes to technology usage [3]. This is compared to most industries that have instilled digitalisation and innovation. As a result, those industries have seen improvement and productivity gains. The adoption of new-age technologies such as Artificial Intelligence (AI) bridges the gap with other industries and developed countries [4].

AI refers to technology that can think independently of humans. It is a constructed, artificial, or machine intelligence, distinguished from natural intelligence by its very definition [5]. AI technologies are as important as those that provoked socially, politically, and environmentally in previous centuries [6]. Some of the construction industry’s AI technologies include Building Information Modelling (BIM), sensor-based technologies, robotics, and wearable technologies [7]. This study aims to identify the influencing factors and strategies of AI adoption using a systematic literature review. This is to improve and assist in adopting AI technologies in the construction industry of developing countries.

2. Methodology
This study adopts a methodological approach to conducting a systematic literature review of influencing factors and AI adoption strategies in the construction industry. Systematic literature review (SLR) is a type of literature review that follows a specific review protocol and quality procedures to select relevant (primary) studies, extract and analyse appropriate information from the selected studies to answer...
specific research questions [8]. This approach can be used to draw logical inferences systematically based on the collected literature. Compared to other approaches, content analysis has the advantage of performing both qualitative and quantitative analyses of AI factors and strategies in the construction industry [9].

Various approaches and steps are taken when doing a systematic literature review with the same outcome [10]. This study took steps performed in accordance with [11].

2.1. Search Strategy

A systematic search was performed to identify the relevant AI articles published in the various databases from 2010 until 2020. Data was collected from ASCE Journals, Emerald Insight, Elsevier ScienceDirect, Engineering Village, Google Scholar, ICE virtual library, IOPscience, IEEE Xplore, Elsevier ScienceDirect, Elsevier Scopus, SpringerLink and Taylor & Francis. When searching for the relevant documents, various search terms were used. Furthermore, Boolean and database-specific operators such as AND, OR, and special characters such as truncation (*) or (?) were associated with the search terms were used [12]. The search terms used were Adoption, Artificial Intelligence, Construction industry, Construction Management, Factors, Influencing Factors, Strategies.

2.2. Inclusion and Exclusion Criteria

This review included empirical studies based on the relevant research topic, AI adoption in the construction industry, written in English and published between 2010 and 2020. Exclusion criteria are any empirical which pieces were excluded if they focused on any other than the construction industry.

A total of 837 articles was extracted from the various databases. Thirty-one duplicate publications were removed. Four hundred and twenty records were excluded as they were either not written in English, show no peer review process, did not focus on AI and the construction industry, leaving 386 studies. These 386 articles abstracts were read, excluding 350 records as they did not look at influencing factors or strategies of AI adoption in the construction industry, and 36 papers were selected for the final classification and analysis. From those papers, 20 papers focused on influencing factors and 16 on strategies. Fig. 1 shows the approach used during the selection of the studies.
3. Results

3.1. Descriptive analysis of the SLR findings

Figure 2 shows the 36 publications that identified AI influencing factors and strategies within the construction industry that has grown from 2010 to 2020, implying that AI is an emerging topic. 2019 has the highest number of publications of 12, while 2005 and 2006 each have one publication.

Figure 3 represents the publications per country. China leads in AI research in the construction industry accounting for eight publications, approximately 23% for articles used in the SLR. Portugal, Singapore, Saudi Arabia and Oman each have one publication.

Figure 4 shows the type of publications that used the SLR. Of the 36 publications used, 26 are journal articles making up approximately 73% of the study.

Figure 5 shows the research method of the publications.
Figure 2: Number of publications per year between 2010 and 2020

Figure 3: Country publications of studies
3.2. Factors Influencing the adoption of AI in the Construction Industry

Table 1 indicates factors influencing the adoption of AI in the construction industry. The most influential factor is the cost of adopting AI with 15 sources. This is closely followed by Skills and expert knowledge with 13 sources. Fragmented industry, improve work culture, internet services and perform technical tasks are the least influential factors. This is together with power supply, professional bodies support and project documentation with one source each.
Table 1: Factors influencing AI adoption

| Influencing Factors                          | Source                                                                 |
|---------------------------------------------|------------------------------------------------------------------------|
| 3D detailing                                | [13], [15],[20],[28]                                                  |
| Clash Detection                             | [13],[20],[28]                                                        |
| Collaboration/communication                 | [15] ,[19],[22],[24],[25],[27],[28]                                   |
| Comparability                               | [14],[17],[18],[23],[30]                                              |
| Complexity                                  | [14],[17],[18]                                                        |
| Cost of adopting AI                         | [14],[15],[16],[18],[19],[20],[21],[22],[23],[24],[25],[26],[28],[29],[31] |
| Costing and estimating                      | [13],[28]                                                             |
| Define project roles and responsibilities    | [13],[28]                                                             |
| Documentation                               | [13],[28]                                                             |
| Facilities Management                       | [13],[28]                                                             |
| Fragmented industry                         | [15]                                                                  |
| Goal Setting                                | [13],[22]                                                             |
| Government support                          | [15],[16],[17],[19],[20],[21],[22],[23],[24],[25],[28],[29]            |
| Improve work culture                        | [15]                                                                  |
| Internet Services                           | [23]                                                                  |
| Legal Security                              | [25],[26],[27]                                                        |
| Market Pressure and Demand                  | [14],[15],[16],[17],[19],[20],[21],[22],[24],[26],[29]                |
| Organisational Readiness                    | [14],[16],[17],[18],[29]                                              |
| Organisational Size                         | [14],[17]                                                             |
| Perform Technical tasks                     | [13]                                                                  |
| Power Supply                                | [23]                                                                  |
| Professional bodies support                 | [19]                                                                  |
| Project documentation                       | [13]                                                                  |
| project effectiveness and productivity      | [13], [15],[28]                                                       |
| project life cycling                        | [13],[20]                                                             |
| Reducing risk factors on project            | [13],[15],[18],[21],[22],[24]                                         |
| Relative Advantage                          | [14],[16],[17],[29]                                                   |
| Resistance to Change                        | [21],[26],[31],[32]                                                   |
| Scheduling                                  | [20],[24],[28]                                                        |
| Site Layout Planning                        | [13],[28]                                                             |
| Skills and expert knowledge                 | [15], [18], [19],[20],[21],[22],[23],[24],[25],[28],[30],[31],[32]   |
| Standardisation                             | [15], [19],[20],[21],[23],[24],[25],[26],[27],[28]                   |
| Successful delivery of project on time, within cost and expected quality | [13], [15],[24],[25],[26],[27],[29]                                  |
Supply Chain [22],[23]
Top management support [13], [14], [15],[16],[17], [18],[22],[23],[28],[29],[30],[32]
Trading Partners Support [14], [29]

3.3. Strategies Influencing the adoption of AI in the Construction Industry

Strategies of AI adoption are indicated in table 2 below. First, training and skills acquisition of personnel cited as a critical strategy in adopting AI in the construction industry. This is followed by AI academia, research and development, and the development of government policies. Next, evaluating Project delivery method, example projects, industry leadership are the least critical strategies of AI adoption. This is followed by measured benchmarks, merger and realistic timescale for adoption.

| Table 2: Strategies of AI adoption |
|-----------------------------------|
| Strategies                        | Sources                                      |
| AI academia, research and development | [36],[37],[38],[39],[40],[43],[46],[47],[48] |
| Benchmarking of best practice      | [37],[39]                                    |
| Change Management                  | [34],[43]                                    |
| Communicating benefits             | [34],[38],[39],[40],[47]                     |
| Communicating with vendors         | [42],[47],[48]                               |
| Development of government policies | [35],[37],[38],[40],[43],[45],[46],[47],[48] |
| Evaluating Project Delivery Method | [44]                                        |
| Example projects                   | [37]                                        |
| Financial incentives for AI adoption | [36],[45]                                 |
| Industry leadership                | [38]                                        |
| Legal contracts and property rights| [38],[41],[43],[48]                          |
| Low-cost loans and subsidies from government and financial institutions | [36],[37],[42],[44],[45],[46],[47],[48] |
| Mandatory AI policies and regulations | [36],[37],[38],[45],[46],[47]              |
| Measured benchmarks                | [34]                                        |
| Merger                             | [33]                                        |
| Provision of trail usage           | [40],[42],[45],[46]                          |
| Public awareness and initiative    | [36],[37],[42],[44],[45],[46],[47]           |
| Realistic timescale for adoption   | [34]                                        |
| Senior Leadership Commitment       | [34],[36],[44],[48]                          |
| Sharing of knowledge of AI technologies | [35],[46]                               |
| Standardisation of AI practice in the construction industry | [33],[35],[37],[38],[39],[43],[46],[47] |
| Training and skills acquisition of personnel | [33],[34],[35],[37],[39],[40],[43],[44],[46],[47],[48] |
4. Conclusion and Future work

This research presented the influencing factors and strategies of AI adoption in the construction industry. This is based on publications made between 2010 and 2020 through a systematic literature review. A total of 36 publications were analysed in the review. It was determined that the number of publications was highest in 2019. However, only seven publications were made in 2017. This implies a decreasing interest in AI in the construction domain.

Geographically, the Asian countries are leading with 29 publications in total, while Nigeria is the only African country with only two publications. Also, it could tell us, Africa lacks in AI research. This could be due to a lot of reasons such as lack of facilities, collaboration and expertise. Thus, focus on expertise and collaboration must be encouraged while the government aids institutions with facilities. From the publications, the cost of adopting AI was found to be the most influential factor. This implies that the construction industry considers the transactional cost which goes with adopting AI. When first adopting AI, the infrastructure and equipment, in the long run, save money time for the organisations.

Training and skills acquisition of personnel was found to be the critical strategy. Stakeholders in various construction organisations are questioning whether AI will increase productivity. They are also curious if AI will eventually replace employees’ existing employment. Organisations are constantly changing. This is accomplished by transitioning to modern technology and software systems to help with a more dynamic approach to employee training and development.

Future studies should combine the literature review knowledge and acquire primary data through interviews and questionnaires. Future research should also look at developing a roadmap of AI adoption in the construction industry, focusing on developing countries.

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