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Artificial Intelligence (AI) Implementation in Improving Construction Site Workflow Performance

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Abstract

In a wide variety of industries, Artificial Intelligence (AI) is having a significant influence on both productivity and economic expansion. Studies found that Malaysia's AI issues are limited AI expertise in the construction industry, risks of privacy violation due to AI, and confronting cultural obstacles on the construction site. Therefore, the objectives of this research are to identify the influencing factors in the use of AI in improving workflow performance in construction site, to identify the challenges in improving construction site workflow performance and to measure relationships between main influencing factors in the use of AI with main challenges of AI in improving construction site workflow performance. This study specifically targeted G7, a contractor company situated in Johor Bahru, as the respondent. It used a quantitative approach to accomplish all of its objectives. This research examines the 226 viewpoints of Grade 7 contractors in Johor Bahru. The participants received a questionnaire via both face-to-face meetings and a link to a Google form sent via WhatsApp and email. Out of the total number of respondents, 101 individuals, making up 45% of the total, have provided feedback in the questionnaire. The data was analysed for all purposes using SPSS software, including descriptive statistics with frequency and crosstabs. This study identified that the main factors and main challenges respectively management of risks and limited AI expertise in the construction industry were reported with the highest frequency. Meanwhile, the correlation between the main factors and with main challenges with strongest relationship is return on investment with sluggish electrical supply. All of these findings give guidelines and information for contractors to improve overall performance, less risk, and increase efficiency. This study opens the door to more focused interventions and calculated methods to address the intricacies present in improving construction site workflow building projects, which will eventually benefit industry stakeholders.

1. Introduction

Many people consider the construction sector to be one of the most difficult fields to work in. This is due to the fact that building projects have qualities that are both complicated and one of a type. For instance, a building project will include workers, workspaces, services, and the nature of the job that are all suited to satisfy the requirements of the project. Additionally, the construction business is considered to be one of the industries with the highest levels of risk (Aripin, Zawawi & Ismail, 2019). This is because of the nature of complex building projects, which affects the activities, processes, environments, and organisations involved in the construction industry. be. The quick adoption of new technologies in countries all around the globe may be connected to this phenomenon. The use of technology in people's day-to-day activities is another way that technology helps people with their day-to-day issues. Because of this, the implementation of adaptable forms of technology (Matarop, 2023).

1.1 Research Background

The construction industry is one of the contributors to the country's economic stability. According to an online newspaper report, Utusan Malaysia, the performance of the construction sector has recorded a very encouraging performance. It was recorded in the fourth quarter of 2022 where the value of construction work has increased by 15.7 percent, which is equivalent to RM32 billion, and it has been confirmed by the Department of Statistics (Nadzari, 2023). The term "Artificial Intelligence" (AI) refers to the process of reproducing human intellect in computers. This is accomplished by training computers to act and think in the same manner as people by using complicated programming (Frankfield, 2023).

AI has an important impact on people's daily lives and plays a vital role in enhancing businesses. In recent years, there has been a significant focus on operations, service processes, and industrial productivity (*Abioye et al.,* 2021). The construction sector is undergoing a fundamental transition as a result of the increased usage of AI, which is being enthusiastically embraced all around the globe. AI is being used in Malaysia in an effort to improve the overall quality of project delivery (Mohamed, Ahmad & Mohamad, 2021). A proficient construction workflow guarantees a seamless progression of tasks, culminating in the successful delivery of the project. Inadequately designed operations and processes can lead to team disharmony, disorder, project delays, and contract cancellations (Kukhnavets, 2023). Ensuring optimal workflow performance is crucial in order to achieve timely project completion within budgetary constraints while maintaining high standards of quality (Weller, 2021).

1.2 Problem Statements

The construction industry still faces difficulties in maximizing workflow performance at building sites, despite advances in technology and project management techniques. Problems including inadequate resource allocation, delayed materials, ineffective work scheduling, and a lack of real-time communication between on-site personnel all add to project delays, higher expenses, and worse quality (Akintoye *et al.,* 2017). Low efficiency and competitiveness resulted from the lack of AI technologies, which will be caused by inefficient plans that were established without the use of AI on the building site. Measuring the benefits of AI presents a number of challenges, the most significant of which is the lack of clarity about the potential returns on initial investments. This uncertainty is being amplified since major construction businesses are still using a conventional method that might be automated, and small subcontractors are following a business model that is comparable to the one used by large construction companies (Regona *et al.,* 2022).

The lack of expert energy in the handling of technology is also linked to one of the reasons why the performance of the construction industry is weak and less productive (Abioye *et al.,* 2021). The lack of AI engineers throughout the world who possess the necessary expertise to steer significant breakthroughs in a variety of sectors. Industrial Revolution 4.0 has shown a significant process in the use of AI in construction, but the construction industry has not yet benefited greatly from AI even though it is facing existing methods (Abioye *et al.,* 2021). Duggal (2023) has shown that there are several elements of relationship strengthening that are not entirely clear. As a result, the purpose of this research is to investigate the challenges faced and potential solutions offered by the absence of an AI approach in the process of enhancing workflow performance at construction sites. As can be observed 3 from this, the present research is still lacking a measurement of the link between the primary drivers of AI and the difficulties in enhancing construction sites' workflow efficiency.

1.3 Research Questions

(i) What are the influencing factors in the use of AI in improving construction site workflow performance?

(ii) What is AI the challenges in improving construction site workflow performance?

(iii) How strength the relationship between main AI influencing factors with main challenges in improving construction site workflow performance?

1.4 Research Objectives

(i) To identify the influencing factors in the use of AI in improving construction site workflow performance.
(ii) To identify the AI challenges in improving construction site workflow performance.
(iii) To analyse relationships between main influencing factors in the use of AI with main challenges of Artificial Intelligence in improving construction site workflow performance.

1.5 Research Hypothesis

(a) H0: There is no significant relationship between main AI influencing factors with main challenges in improving construction site workflow performance.
(b) H1: There is a significant relationship between main AI influencing factors with main challenges in improving construction site workflow performance.

1.6 Research Scope

This research focuses on the most recent technological advancement, known as AI, which has already made its way into the field of construction. This is due to the fact that the use of AI in construction companies has the potential to elevate it to the position of being the most productive sector (Akinosho *et al.,* 2020). The location to get the data is in Johor Bahru. This is because the state of Johor is the second highest state recording the number of projects in the private sector. Johor is also the third highest state in the government sector, and this is confirmed by the report of the Ministry of Public Works (KKR) (2018) (Latiffi, 2021). With this it is clear that shows the construction activity is so fast carried out in the state. Respondents for this study focused on grade 7 (G7) contractors. This is because, by district in the state of Johor, Johor Bahru is the district with the highest number of grade (G7) contractors (CIDB, 2023). CIDB reports that there are a total of 527 grade 7 (G7) construction companies registered with the organization for the state of Johor Bahru (CIDB, 2023). Certification in the ISO 9000 Quality Management System is now required of all grades 7 (G7) contractors according to a mandate from the Construction Industrial Development Board (CIDB). If this is not accomplished, the ratings of the firm will be lowered, which will have repercussions for the way in which they conduct their business (Marhani *et al.,* 2012). A growing number of construction companies have started the process of obtaining ISO certification in an attempt to address concerns such as inferior building materials and craftsmanship, in addition to the accompanying delays, accidents, and environmental implications (Khan, Liew & Razali, 2014).

1.7 Significance of Study

It is vital to do the study in order to identify the AI approach that will improve the workflow performance at building sites. The following entities and individuals may benefit from the findings of this study. For the contractor, they can have a better understanding of the primary considerations involved in 4 applying AI to the building sector. In addition, contractors could look into the difficulties involved in using AI to improve construction site workflow performance. So, the contractors can gain many benefits. Other than that, the findings of this research provide insight to many organizations on the significance of using AI while working on a building project. In addition to this, it provides the organization with the opportunity to get exposure to a wide view of the challenges that the use of AI technology faces in the construction sector. Because of this, organizations in the construction industry now have the opportunity to implement the use of AI in a more active manner inside the construction industry, which will ultimately result in improved prospects for the future of the organization. Last but not least, the findings of the study might serve as a reference at some point in the future for other professionals like students, future researchers and educators. It is probable that the study might outcome in newly formed information and a deeper comprehension of the AI implementation in improving construction site workflow performance for those individuals who are interested in future research.

2. Literature Review

2.1 The Influencing Factors In the use of AI In Improving Construction Site Workflow Performance

The utilization of AI has become growing increasingly common in the construction industry, representing a significant shift in various sectors. It creates pressure for technological advancement. AI is receiving significant attention in the construction industry as a novel strategic tool (Tjebane, Musonda & Okoro, 2022). The following 9 influencing factors in the use of ai in improving construction site workflow performance.

(a) *Technologically*

AI plays an extremely important part as a significant facilitator of information processing capabilities to digest an ever-increasing amount of data. As a direct consequence of this, businesses that have a stronger need for the processing of information are anticipated to be more receptive to the incorporation of AI (Ghobakhloo & Ching, 2019).

(b) *Return on investment (ROI)*

The creation of parts may be adapted to specific requirements by AI, which can then be used to facilitate the development of more efficient construction practices. It lessens the dangers that employees face on typical building sites and, as a result, lowers the total cost of construction (Turner *et al.,* 2020).

(c) *Management of risks*

The performance of the workflow on construction sites may be greatly improved by giving consideration to risk management techniques and incorporating AI technologies to increase risk analysis and decision-making processes (Malsam, 2022). Managers of projects are able to swiftly respond to new difficulties, such as the effect a pandemic may have on a shortage of workers when they use AI to manage risk. Due to the fact that AI is both predictive and able to act in real time, it is much simpler to react promptly to new and ongoing issues (Skinner, 2023).

(d) *Organization culture and change management*

The organizational culture of construction companies and their capacity to adapt to change are two factors that determine the effective adoption of AI. The adoption of AI is significantly impacted by a variety of factors, including leadership backing, staff training, and change management tactics (Bley *et al.,* 2022).

(e) *Data availability and quality project*

With the help of AI, the data can be evaluated in real time, allowing for the identification of possible problems and flaws at an earlier stage (Marketing Indovance, 2023). The massive volume of data necessitates the use of sophisticated data analytics strategies in order to transform it into knowledge that can be used for the reduction of waste. Because of this, it is imperative that they make use of strategies that AI in order to manage waste effectively and made the better quality of workflow performance (Abioye
et al., 2021).

(f) *Industry standards and best practices*

The establishment of norms, frameworks, and benchmarks by standards helps to ensure that artificial intelligence systems are of a high quality, are compatible with one another, and can be relied upon (Abioye *et al.,* 2021). According to Mikalef & Gupta (2021), research studies have been carried out, and they are backed up by empirical data, on the topic of establishing AI capabilities by generating a one-of-a-kind collection of resources that are able to successfully leverage investments and produce commercial value, ultimately leading to a competitive advantage.

(g) *Operational efficiency and optimize outcomes*

Questions about reliability and privacy concerns, as well as the reluctance of senior personnel in the sector, have led to the development of revolutionary AI technology. Managers are willing to accept and even embrace new technology that will make them more effective in their roles as leaders (Holzmann & Lechiara, 2022). Consistent with prior research, it has been posited that the utilization of technology can facilitate project managers in advancing operational effectiveness, fostering team development, and enhancing proficiency (Kaplan & Haenlein, 2019).

(h) *Human intervention*

The process of developing a building plan is greatly aided by the use of AI. AI refers to the capabilities of autonomous technology. Because it is aware of its surroundings and has the ability to navigate without assistance from a person. During the planning phases, artificial machines may be used to survey a prospective building site in order to acquire sufficient information for the creation of 3D maps, drawings, and construction plans. AI has

transformed what used to be a laborious and time-consuming procedure into something that can now be accomplished in a single day. Companies are able to save costs and save time as a result of this (Parveen, 2018).

(i) *Excessive spending*

According to Blanco *et al* (2018) found that while the construction industry is slower to implement AI compared to other sectors, AI has the ability to alleviate the problem of cost overruns by assisting construction businesses in reducing their overhead expenditures. The implementation of automated systems for routine tasks and procedures has the potential to yield substantial cost savings, thereby potentially increasing both revenue and profit margins. The subsequent discourse elucidates the potential of artificial intelligence in facilitating cost savings during the different stages of a construction project, spanning its entire lifespan (Alice Technologies, 2022).

2.2 The AI Challenges in Improving Construction Site Workflow Performance

The construction sector is plagued by several difficulties, which have stymied its expansion and resulted in exceptionally inadequate levels of productivity when compared with competing industries, such as manufacturing (Abioye *et al.,* 2021). There are other challenges in implementing AI to improve construction site workflow performance.

(a) *Validation and acceptance in AI*

In a similar vein, there should be a delay in the implementation of data science and machine learning. This occurs as a result of a lack of knowledge of the advantages, a fear of becoming obsolete, and a difficulty in gaining access to the relevant technology (Editorial Team, 2022). Babic and Rebolj (2016) stated the construction industry favours the tried-and-true methods that have been used for decades over the innovative but unproven technology that promise to bring in significant gains (Abioye *et al.,* 2021).

(b) *Limited AI expertise in the construction industry*

One contributing factor to the AI skills shortage is the inadequacy of current educational and training programs to keep pace with the swift advancements and innovations in the field of AI. Professionals in 6 the field of AI are expected to possess not only formal education but also practical experience. Consequently, a dearth of seasoned AI professionals exists, rendering them inadequate to assume the requisite leadership roles for companies that are in the nascent stages of integrating AI tactics into their business operations (Marr, 2018).

(c) *Greater starting investment required for AI*

The deployment of AI sometimes calls for substantial expenditures in computer hardware, computer software, and trained staff. Because construction projects often have limited budgets and resources, it might be difficult to dedicate resources for the adoption and maintenance of AI technologies (Reilly, 2023). It is imperative for organizations, even those with the financial means to cover the expenses associated with implementation, to undertake a thorough cost-benefit analysis. This analysis facilitates the identification of potential cost reductions and the calculation of the return on investment (ROI) (Urie, 2023).

(d) *Occurs in a complex and dynamic environment*

The implementation of AI in real-world settings is made much more challenging by the fact that outside environmental conditions and non-standardized building designs complicate matters. As a consequence of this, the sector is progressively adopting AI technology in its day-to-day operations in order to facilitate the transition from a conventional hierarchical structure to a digital and more autonomous one (Regona *et al.,* 2022).

e) *Empowerment poses challenges to achieving explainability and trust*

Explainability and trustworthiness are of the utmost importance in sectors that are very safety conscious, such as the construction industry. It may be difficult to guarantee that the outputs that AI systems produce are both visible and interpretable (Philip, 2019). The absence of transparency inside AI systems may result in a lack of confidence, which, in turn, can slow down the rate at which these systems are adopted. It is essential to have AI systems that are both transparent and able to be interpreted for them to gain widespread acceptance (Mahmood, 2023).

(f) *Risks of privacy violation due to AI*

The use of AI in the construction industry may include the acquisition and processing of sensitive data, such as personal information and project plans and specifications. It is essential to protect data privacy and ensure cybersecurity in AI systems, but doing so may be difficult owing to the constantly shifting nature of cyber threats and the need for stringent security measures (Kuzlu, Fair & Guler, 2021).

(g) *Sluggish electrical service and broken connections to the web*

This presents a significant challenge for the use of AI technologies on construction sites, the functioning of which is mostly dependent on a reliable supply of electricity and internet connection (for example, robots and site monitoring systems, among other things) (Abioye *et al.,* 2021). On building sites, disruptions to electricity, telecommunications, and internet connection may provide a substantial challenge when attempting to make use of some AI applications (Urie, 2023).

(h*) Increasing deployment and job creation*

The labor market is seeing enormous changes as a direct result of the rise of AI. According to "The Future of Jobs Report" (2020) published by the World Economic Forum, AI will be responsible for the displacement of 85 million jobs throughout the world by the year 2025. More than 50% of these occupations are most likely to be eliminated during the third wave when robots take over routine work (PBCToday, 2018).

(i) *Confronting cultural obstacles on the construction site*

Traditional techniques are given precedence over experimental technology because of the inherent dangers of the construction industry, in which mistakes may have significant ramifications for a company's bottom line. The construction sector is notorious for its highly fragmented landscape, which 7 makes change particularly challenging. A successful shift from past models to future models requires maintaining consistent practices in terms of site operation, design, management, and employment requirements (Regona *et al.,* 2022).

(j) *Legal concerns as well as regulatory difficulties*

There is a possibility that the use of AI in the construction business will be subject to a variety of rules and regulatory restrictions. When it comes to the development and deployment of AI solutions, one of the issues that may arise is ensuring compliance with data protection regulations, intellectual property rights, and ethical principles (Parveen, 2018).

2.3 Relationship Between AI Influencing Factors with Challenges in Improving Construction Site Workflow Performance

The construction industry is gradually adopting digital processes, real-time data capture, site monitoring, and data analysis. Another technical advancement has garnered substantial attention in this context. AI is expected to impact this business, as it has already transformed others (Golstein & Branthonne, 2020). AI technology is influencing the construction process because of its potential for future advancements. Computing and data analysis in the construction business sometimes provide important but unutilized information (Kumar, 2022). The prior research and literature reveal a significant knowledge gap on the relationship between factors affecting construction site workflow performance and associated challenges. No earlier study has examined the interconnectedness of these factors and their impact on construction workflow performance. There is a knowledge gap that needs additional inquiry and analysis to close.

3. Research Methodology

3.1 Research Design

(a) Procedure of Research

The research methodology that applies to this study is presented in Appendix A. This study is conducted in five phases. The whole phase often represents the entire research process.

(b) Research Method

This study employs quantitative methodology to accomplish all of its objectives. Quantitative research is a methodology that presents its results in numerical form. Quantitative research is conducted by formulating

specific questions and surveys that are directly related to the study's objectives. These questions are designed in an organized format.

(c) Respondent

The present research used the Krejcie & Morgan (1970) Table to determine the appropriate sample size. Furthermore, the population under study consists of contractors who have enrolled in Grade 7. The estimated population size in Johor Bahru is around 527 respondents, according to CIDB (2023). Hence, the sample size is around 226 (Refer Appendix B).

(d) Research Instrument

The questionnaire was mainly used to assess contractors' degree of agreement with the factors that influence the use of AI to improve the workflow performance of construction sites, the AI challenges in improving construction site workflow performance, and the relationship between influencing factors in the use of AI with AI challenges in improving construction site workflow performance. Likert five-point Likert scales, ranging from strongly agree to strongly disagree, are used to frame questions. There were Sections A, B, C, and D. The background of the respondents is covered in Section A. The influencing factors in the use of AI in improving construction site workflow performance are covered in Section B. AI challenges in improving construction site workflow performance are covered in Section C. For the questionnaire form, refer Appendix C.

3.2 Pilot Study

The research conducted pilot study devised a set of questions that were answered by 7 participants in Johor Bahru have answered the online questionnaire provided. According to Bullen (2021), the optimal number of respondents for the pilot research phase is 10. This number was chosen since it is a flexible one that allows for the best possible first response. The pilot study is one of the major stages of this research, and its purpose is to identify possible issue areas and shortcomings in research instruments and procedures before a performance throughout the time of complete research (Hassan *et al.,* 2006)

(a) *Reliability Analysis*

Cronbach's alpha was used to assess the reliability of Likert scale surveys consisting of numerous questions. The inquiry concerns the evaluation of latent variables, which are abstract or hidden properties such as an individual's degree of precision, irritability, or openness (Glen, 2021). The following guideline may be used to assess the quality of a measure: if $\alpha > 0.9$, it is considered Excellent; if $\alpha > 0.8$, it is considered Good; if $\alpha > 0.7$, it is considered Acceptable; if $\alpha > 0.6$, it is considered Questionable; if $\alpha > 0.5$, it is considered Poor; and if $\alpha < 0.5$, it is considered Unacceptable. The reliability study of the collected data reveals a Cronbach's Alpha value of 0.939, as shown in Table 1. This indicates that the questionnaire is trustworthy, and the items demonstrate a satisfactory level of internal consistency.

Table 1 *Reliability Test*

Number of Questions	Number of Respondents	Alpha Cronbach's Value
65	7	0.939

3.3 Data Collection

A total of 101 contractors in Johor Bahru who were in Grade 7 were given an online questionnaire to fill out to obtain the data that was collected and obtained. In addition to being produced using a manual form set (in person), the questionnaire was also designed online through the use of a Google form template. The link to the Google form was sent across many platforms, including WhatsApp and email.

3.4 Data Analysis

Prior to implementing the findings, it is important to gather and verify the outcomes of data analysis throughout the research process. The Statistical Package for the Social Sciences (SPSS) software provided a precise outcome. The major instrument used by the researcher to gather data for this study was the Likert Scale Questionnaire. The data gathered and presented in the form of a table, a graph, and a pie chart.

4. Results and Discussions

The study's data and analysis are shown in the findings and discussion section. Among the sample size 226, a total of 101 sets of questionnaires were returned with responses, and all of the returned questionnaires were used for data analysis. As a result, 45% of the total questionnaires issued to construction companies Grade 7 that located in Johor Bharu responded to the survey. As a result of the validity of the analysis, the study's response rate is 45 % accordant to Keeter *et al.,* (2006) who shown that surveys with low response rates (around 20%) produced more reliable results than surveys with higher response rates (around 60% to 70%).

(a) Section A: Respondent's Background

This section includes the overall response pattern as well as sample characteristics of typical responders. In addition, Table 2 displayed the table summarising the data analysis from Section A. At 54%, the proportion of male respondents out of a total of 54 respondents is greater than that of female respondents. 9 The largest number, 74%, with 75 responders, pertains to those between the ages of 30 and 49 years. Additionally, out of 63 responses, Malay makes up the largest race with 63%. Additionally, of the 78 responders, 77% had the greatest qualifications for a degree. With 74 responders, the next greatest proportion of years of service in the construction business is between 11 and 20 years, at 74%. Engineers have the greatest proportion of job titles with 26%, or 27 responses.

Table 2 *Summary of data analysis in Section A*

No. Respondents Background	Frequency	Percentage (%)
1. Gender		
Male	54	54%
Female	46	46%
2. Age		
Between 18 to 29 years old	25	25%
Between 30 to 49 years old	75	74%
Between 50 to 59 years old	1	1%
60 years old and above	0	-
3. Race		
Malay	63	63%
Indian	11	11%
Chinese	26	26%
Other	1	1.0%
4. Highest Qualifications		
Primary/Secondary	0	-
Diploma	15	15%
Degree	78	77%
Master/Ph.D.	8	8%
5. Years of Service in Construction Industry		
Between 1 to 5 years	7	7%
Between 6 to 10 years	18	18%
Between 11 to 20 years	75	74%
21 years and above	1	1%
6. Job Title		
Architect	24	24%
Engineer	27	26%
Project Manager	16	16%
Quantity Surveyor	16	15%
Site Supervisor	14	15%
Other	4	4%

(b) Section B: Influencing Factors in the Use of AI in Improving Construction Site Workflow Performance (Objective 1)

The analysis of mean is based on Table 3, the mean average score is categorized into three levels: low, moderate and high.

Table 3 *Assessment level based on mean score (Ibrahim, 2013)*

Mean Score Range	Level	Mean Score
1.00-2.33	Low	(Not Agree/ Not Helpful/ Unsatisfied/ None/ Sometimes/Not Sure)
2.34-3.66	Moderate	(Agree/ Helpful/ Satisfied)
3.67-5.00	High	(Strongly Agree/ Fully Satisfied/ Really Helpful)

Based on Table 4, the majority of respondents achieved a high agreement level (refer Table 3) that main factors in improving construction site workflow performance is management of risks with the highest mean value, 4.4530. Next, followed by high technologically, data availability and industry standard practices which the mean value is 4.4332, 4.3465 and 4.3333 respectively. Furthermore, some of respondents strongly agreed (high of agreement level) that the main factors are human intervention with a mean value of 4.3069. According to the data analysis of the returned questionnaires, the respondents 10 achieved all high of agreement level for all the main factors.

Table 4 *Mean analysis of main factors in improving construction site workflow performance*

No.	Influencing Factors in the Use of AI in Improving Construction Site Workflow Performance.	Mean	Agreement Level	Ranking
Technologically		4.4332	High	2
1.	Significant facilitator	4.3365	High	3
2.	Real with virtual worlds	4.3267	High	4
3.	Automate processes	4.5149	High	2
4.	Speed up processes	4.5545	High	1
Return on Investment		4.1881	High	8
5.	Efficient practices	4.1188	High	3
6.	Satisfactory on income	4.1386	High	2
7.	Reduction in expenses	4.3069	High	1
Management of Risks		4.4530	High	1
8.	Risk analysis	4.3465	High	4
9.	Decision-making processes	4.4554	High	3
10.	React quickly to new problems	4.5446	High	1
11.	Monitor the progression	4.4653	High	2
Organization Culture		4.2277	High	7
12.	Encourages a collective goal	4.2178	High	2
13.	Overcome anticipated team anxiety	4.0792	High	3
14.	Connection with technologies	4.3861	High	1
Data Availability		4.3465	High	3
16.	Make accurate forecasts	4.2376	High	3
17.	Use data responsibly-2	4.2970	High	2
18.	High performance quality	4.5050	High	1
Industry Standard Practices		4.3333	High	4
19.	Unbiased system	4.1386	High	3
20.	Have a positive purpose	4.3861	High	2
21.	Optimize project's capability	4.4752	High	1
Human Intervention		4.3069	High	5
22.	Acquire sufficient information	4.2574	High	2
23	Save costs	4.1683	High	3
24.	Time consuming procedure short	4.4950	High	1
Excessive Spending		4.2673	High	6
25.	Reduced expenditures	4.2178	High	3
26	Cost savings	4.2079	High	4
27.	Increasing revenue	4.2970	High	2
28.	Increasing profit margins	4.3465	High	1

According to the analysis of the research, the main factor in the use of the AI in improving construction site workflow performance is management of risks with the highest mean value, 4.4530. Meanwhile, the lowest mean of the main factor in improving construction site workflow performance is 4.1881, which is return on investment.

This is because a majority of the respondents think that return on investment is less influential to be the main factor in improving construction site workflow performance. Based on research findings, these are related Malsam (2022) says that the project manager should possess diligence and knowledge regarding potential obstacles that may disrupt operations. Thus, with this the first objective, which is to identify the influencing factors in the use of AI in improving construction site workflow performance has been achieved.

c) Section C: AI Challenges in Improving Construction Site Workflow Performance (Objective 2)

Based on Table 5, the majority of respondents achieved high agreement level (refer Table 3) that main challenges in improving construction site workflow performance is limited AI expertise in the construction industry with the highest mean of 4.5016. Followed by risks of privacy violation, sluggish electrical service and validation and acceptance of AI which the mean value is 4.4356, 4.4290 and 4.3564. Furthermore, some of respondents strongly agreed (high of agreement level) that the greater starting investment required for AI with a mean value of 4.3003. According to the data analysis of the returned questionnaires, the respondents achieved all high of agreement level for all the main challenges in improving construction site workflow performance.

Table 5 *Mean analysis of AI challenges in improving construction site workflow performance*

No.	AI Challenges in Improving Construction Site Workflow Performance.	Mean	Agreement Level	Ranking
Validation and acceptance of AI		4.3564	High	4
1.	Judgement on AI	4.3663	High	2
2.	Lack of knowledges on AI	4.3762	High	1
3.	Hard to win stakeholders' confidence	4.3267	High	3
Limited AI expertise in the construction industry		4.5016	High	1
4.	AI skills shortage	4.4653	High	3
5.	Hard to find construction AI experts	4.4851	High	2
6.	Invest more money for training	4.5545	High	1
Greater starting investment required for AI		4.3003	High	5
7.	Hard to allocate resources	4.1386	High	3
8.	Invest more maintenance	4.3861	High	1
9.	More work for the investor	4.3762	High	2
Occurs in a complex and dynamic environment		4.1947	High	9
10.	Unpredictability building sites activities	4.1980	High	2
11.	Non-standardized building designs	4.1386	High	3
12.	Navigating the complexities	4.2475	High	1
Empowerment		4.2541	High	6
13.	Slow down the rate	4.0495	High	3
14.	Lack of confidence	4.3366	High	2
15.	Lack of training data	4.3762	High	1
Risks of privacy violation		4.4356	High	2
16.	Cyber security	4.4455	High	2
17.	Unauthorized access to personal information	4.4554	High	1
18.	Exploit vulnerabilities in systems	4.4059	High	3
Sluggish electrical service		4.4290	High	3
19.	Disruptions to the supply of electricity	4.3960	High	2
20	Disruptions of internet connection	4.3960	High	2
21.	Too reliable supply	4.4950	High	1
Increasing deployment		4.1551	High	10
22.	Robots take over routine work	4.1683	High	2
23	Increased demand for workers	3.9505	High	3
24.	Increased unemployment	4.3465	High	1
Confronting cultural		4.2541	High	6
25.	Work procedure is complicated	4.2574	High	2
26.	Inherently hazardous	4.1188	High	3
27.	Still use traditional techniques	4.3861	High	1
Legal concerns difficulties		4.1980	High	8

28.	Violation of the idea of human respect	4.1485	High	3
29.	Low strict data protection laws	4.1485	High	2
30.	Potential be used for harmful purposes	4.3663	High	1

The main challenges in improving construction site workflow performance is limited AI expertise in the construction industry with the highest mean of 4.5016. Therefore, the main challenges in improving construction site workflow performance, namely limited AI expertise in the construction industry could be the greatest challenges in improving construction site workflow performance. Meanwhile, the lowest 12 mean is 4.1551, which is increasing deployment. This is because the majority of respondents believe that focusing on the increasing deployment is not the tiny challenges in improving construction site workflow performance. This finding is in line with Urie (2023), Regona *et al.,* (2022) and Reily (2023) that mention the integration of AI into manufacturing, close collaboration between academic researchers and industry professionals in construction is crucial. Thus, with this the second objective, which is to identify the main challenges in improving construction site workflow performance, has been achieved.

(d) Section D: Strength of Relationship Between Main Influencing Factors in the use of AI with Main AI Challenges in Improving Construction Site Workflow Performance. (Objective 3)

Table 6 shows the approximate significance for the variable's must < 0.05 and value must < 0.5 to show there is a relationship between the variables and there is a strong or a weak relationship. The approximate significance is related to variables. There are two types of hypotheses in this study which are H0 and H1. There is a significant relationship between main AI influencing factors with main challenges in improving construction site workflow performance (H1). There is no significant relationship between main AI influencing factors with main challenges in improving construction site workflow performance (H0). The optimal number of variables to include in a prediction model is not set and often relies on several circumstances. The "one in five rules," a frequently employed method in classical prediction modelling, restricts the number of variables or parameters that may be predicted from a given data set (Chowdhury *et al.,* 2020). In addition, this analysis was carried out by choosing 3 main ranking variables for each aspect of influencing factors in the use of AI. According to McCombes *et al.,* (2022) These variables were chosen because they had a high level of agreement by the respondents and made the items that were most important to achieve the objectives of this study. The variables that have been selected and identified are also common knowledge among the respondents. The same goes for the second objective which is AI challenges in improving construction site workflow performance which is measured from the position of all the variables under the step and it is selected based on the highest strength value of each item (McCombes *et al.,* 2022).

Table 6 *Crosstab analysis (DeFranzo, 2010)*

Appr.Significant	Value	Explanation
< 0.05	< 0.5	There is a relationship between the variables and the relationship is strong (H_1 is accepted)
> 0.05	> 0.5	There is no association between the variables and the relationship is weak (H_0 is accepted)

Table 7 and Appendix D shows the value and approximate significance of the main factors and main challenges. The main factor is Return on Investment with the subfactors satisfactory on income is having the highest ranking in the correlation between factors and challenges (sluggish electrical service) with a value of 0.2840 and the approximate significant is 0.0040, less than 0.05. The main factor is Technologically with the subfactors significant facilitator having the lowest ranking in the correlation between factors and challenges (limited AI expertise in the construction industry) with a value of 0.7350 and the approximate significant is 0.0010, less than 0.05. This result can be concluded as the hypothesis is accepted (H1) because it relates to a strong relationship.

Table 7 *Relationship analysis for main factors with main challenges*

Main Factors	Main Challenges	Approximate Significant	Value	Hypothesis	Ranking
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.6760 (Weak)	H1	10
	Risks of privacy violation	0.0010	0.4900	H1	7

	- Unauthorized access to personal information	(Yes)	(Strong)		
Management of Risks - React quickly to new problems	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.4830 (Strong)	H1	6
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.4940 (Strong)	H1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.5010 (Weak)	H1	9
	Empowerment - Lack of training data	0.0010 (Yes)	0.3700 (Strong)	H1	4
	Confronting Cultural - Still use traditional techniques	0.0010 (Yes)	0.3810 (Strong)	H1	3
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.3580 (Strong)	H1	2
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.3990 (Strong)	H1	5
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.3190 (Strong)	H1	1
Management of Risks - Monitor the progression	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.6760 (Weak)	H1	10
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.3410 (Strong)	H1	3
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.5090 (Weak)	H1	6
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.5260 (Weak)	H1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.5330 (Weak)	H1	9
	Empowerment - Lack of training data	0.0010 (Yes)	0.4620 (Strong)	H1	4
	Confronting Cultural - Still use traditional techniques	0.0020 (Yes)	0.3030 (Strong)	H1	1
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.5220 (Weak)	H1	7
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0020 (Yes)	0.3040 (Strong)	H1	2
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.4970 (Strong)	H1	5
Management of Risks - Decision-making processes	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.7160 (Weak)	H1	10
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.4490 (Strong)	H1	4
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.5120 (Weak)	H1	7
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.5910 (Weak)	H1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.6160 (Weak)	H1	9
	Empowerment	0.0010	0.4140	H1	1

	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.4420	H1	2
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4490	H1	4
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.4490	H1	4
	Environment	(Yes)	(Strong)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.4870	H1	3
	- Increased unemployment	(Yes)	(Strong)		
	Limited AI expertise in the	0.0010	0.5720	H_1	10
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.4240	H_1	2
	- Unauthorized access to personal information	(Yes)	(Strong)		
	Sluggish electrical service	0.0010	0.5350	H_1	8
	- Too reliable supply	(Yes)	(Weak)		
	Validation and acceptance of AI	0.0010	0.4240	H_1	2
	- Lack of knowledges on AI	(Yes)	(Strong)		
Technologically	Greater starting investment required	0.0010	0.5570	H_1	9
- Speed up	for AI	(Yes)	(Weak)		
processes	- Invest more maintenance				
	Empowerment	0.0010	0.4450	H_1	4
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.4050	H_1	1
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4850	H_1	6
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.4450	H_1	4
	Environment	(Yes)	(Strong)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.5340	H_1	7
	- Increased unemployment	(Yes)	(Weak)		
	Limited AI expertise in the	0.0010	0.5630	H_1	10
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.5480	H_1	9
	- Unauthorized access to personal information	(Yes)	(Weak)		
	Sluggish electrical service	0.0010	0.4430	H_1	3
	- Too reliable supply	(Yes)	(Strong)		
Technologically	Validation and acceptance of AI	0.0010	0.4620	H_1	4
- Automate	- Lack of knowledges on AI	(Yes)	(Strong)		
processes	Greater starting investment required	0.0010	0.4690	H_1	5
	for AI	(Yes)	(Weak)		
	- Invest more maintenance				
	Empowerment	0.0010	0.3710	H_1	2
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.3520	H_1	1
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4840	H_1	6
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.5300	H_1	8
	Environment	(Yes)	(Weak)		
	- Navigating the complexities	0.0010	0.4930	H_1	7
	Increased Deployment	(Yes)	(Strong)		

	- Increased unemployment				
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.7350 (Weak)	H_1	9
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.4410 (Strong)	H_1	2
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.5500 (Weak)	H_1	4
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.4770 (Strong)	H_1	3
Technologically - Significant facilitator	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.5720 (Weak)	H_1	5
	Empowerment - Lack of training data	0.0010 (Yes)	0.5860 (Weak)	H_1	7
	Confronting Cultural - Still use traditional techniques	0.0560 (No)	0.2740 (Strong)	H_0	-
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.5950 (Weak)	H_1	8
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.4190 (Strong)	H_1	1
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.5850 (Weak)	H_1	6
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.7280 (Weak)	H_1	9
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.3620 (Strong)	H_1	2
	Sluggish electrical service - Too reliable supply	0.0550 (No)	0.4950 (Strong)	H_0	-
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.5020 (Weak)	H_1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.4930 (Strong)	H_1	7
	Empowerment - Lack of training data	0.0010 (Yes)	0.3980 (Strong)	H_1	3
	Confronting Cultural - Still use traditional techniques	0.0020 (Yes)	0.2980 (Strong)	H_1	1
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.4590 (Strong)	H_1	6
Data Availability - High performance quality	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.4300 (Strong)	H_1	5
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.4270 (Strong)	H_1	4
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.4430 (Strong)	H_1	6
	Risks of privacy violation - Unauthorized access to personal information	0.0020 (Yes)	0.3010 (Strong)	H_1	2
Data Availability	Sluggish electrical service	0.0020	0.3110	H_1	3

- Use data responsibly	- Too reliable supply	(Yes)	(Strong)		
	Validation and acceptance of AI	0.0010	0.3430	H_1	4
	- Lack of knowledges on AI	(Yes)	(Strong)		
	Greater starting investment required	0.0010	0.3850	H_1	5
	for AI	(Yes)	(Strong)		
	- Invest more maintenance				
	Empowerment	0.0540	0.2240	H_0	-
	- Lack of training data	(No)	(Strong)		
	Confronting Cultural	0.0510	0.3950	H_0	-
	- Still use traditional techniques	(No)	(Strong)		
	Legal Concerns Difficulties	0.0030	0.2930	H_1	1
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.5030	H_1	7
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0570	0.2670	H_0	-
	- Increased unemployment	(No)	(Strong)		
	Limited AI expertise in the	0.0010	0.5050	H_1	8
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
	Risks of privacy violation	0.1000	0.2550	H_0	-
	- Unauthorized access to personal information	(No)	(Strong)		
	Sluggish electrical service	0.0010	0.3900	H_1	3
	- Too reliable supply	(Yes)	(Strong)		
	Validation and acceptance of AI	0.0010	0.3740	H_1	1
Data Availability	- Lack of knowledges on AI	(Yes)	(Strong)		
- Make accurate	Greater starting investment required	0.0010	0.5130	H_1	9
forecasts	for AI	(Yes)	(Weak)		
	- Invest more maintenance				
	Empowerment	0.0010	0.4150	H_1	4
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.3780	H_1	2
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4170	H_1	5
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.4650	H_1	7
	Environment	(Yes)	(Strong)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.4550	H_1	6
	- Increased unemployment	(Yes)	(Strong)		
	Limited AI expertise in the	0.0010	0.6780	H_1	8
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
Industry	Risks of privacy violation	0.0010	0.3810	H_1	2
Standard	- Unauthorized access to personal information	(Yes)	(Strong)		
Practices	Sluggish electrical service	0.0010	0.5120	H_1	3
- Optimize project's capability	- Too reliable supply	(Yes)	(Weak)		
	Validation and acceptance of AI	0.0010	0.5290	H_1	4
	- Lack of knowledges on AI	(Yes)	(Weak)		
	Greater starting investment required	0.0010	0.5690	H_1	6
	for AI	(Yes)	(Weak)		
	- Invest more maintenance				
	Empowerment	0.0010	0.5370	H_1	4
	- Lack of training data	(Yes)	(Weak)		
	Confronting Cultural	0.0580	0.2190	H_0	-
	- Still use traditional techniques	(No)	(Strong)		

	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.5910 (Weak)	H_1	7
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.3280 (Strong)	H_1	1
	Increasing Deployment - Increased unemployment	0.0590 (No)	0.2600 (Strong)	H_0	-
Industry Standard Practices - Have a positive purpose	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.4610 (Strong)	H_1	7
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.5090 (Weak)	H_1	10
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.5070 (Strong)	H_1	6
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.5230 (Weak)	H_1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.5480 (Weak)	H_1	9
	Empowerment - Lack of training data	0.0010 (Yes)	0.3840 (Strong)	H_1	1
	Confronting Cultural - Still use traditional techniques	0.0010 (Yes)	0.3980 (Strong)	H_1	2
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.4020 (Strong)	H_1	3
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.4980 (Strong)	H_1	5
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.4120 (Strong)	H_1	4
Industry Standard Practices - Unbiased system	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.4350 (Strong)	H_1	6
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.3330 (Strong)	H_1	2
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.3590 (Strong)	H_1	4
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.4690 (Strong)	H_1	8
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.4370 (Strong)	H_1	7
	Empowerment - Lack of training data	0.0010 (Yes)	0.3170 (Strong)	H_1	1
	Confronting Cultural - Still use traditional techniques	0.0540 (No)	0.2240 (Strong)	H_0	-
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.3830 (Strong)	H_1	5
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.5240 (Weak)	H_1	9
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.3720 (Strong)	H_1	3
	Limited AI expertise in the construction industry	0.0010 (Yes)	0.4880 (Strong)	H_1	4

	- Invest more money for training				
	Risks of privacy violation	0.0010	0.5030	H_1	5
	- Unauthorized access to personal information	(Yes)	(Weak)		
	Sluggish electrical service	0.0010	0.4210	H_1	2
	- Too reliable supply	(Yes)	(Strong)		
Human	Validation and acceptance of AI	0.0010	0.5310	H_1	7
Intervention	- Lack of knowledges on AI	(Yes)	(Weak)		
- Time	Greater starting investment required	0.0010	0.5380	H_1	8
consuming	for AI	(Yes)	(Weak)		
procedure	- Invest more maintenance				
short	Empowerment	0.0010	0.4430	H_1	3
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.4490	H_1	9
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.3820	H_1	1
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.6400	H_1	10
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.5200	H_1	6
	- Increased unemployment	(Yes)	(Weak)		
	Limited AI expertise in the	0.0010	0.4890	H_1	8
	construction industry	(Yes)	(Strong)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.3580	H_1	2
	- Unauthorized access to personal information	(Yes)	(Strong)		
	Sluggish electrical service	0.0010	0.3340	H_1	1
	- Too reliable supply	(Yes)	(Strong)		
Human	Validation and acceptance of AI	0.0010	0.4050	H_1	6
Intervention	- Lack of knowledges on AI	(Yes)	(Strong)		
- Acquire	Greater starting investment required	0.0010	0.4000	H_1	5
sufficient	for AI	(Yes)	(Strong)		
information	- Invest more maintenance				
	Empowerment	0.0010	0.3790	H_1	3
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0590	0.2580	H_0	-
	- Still use traditional techniques	(No)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.3800	H_1	4
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.4740	H_1	7
	Environment	(Yes)	(Strong)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.5130	H_1	9
	- Increased unemployment	(Yes)	(Weak)		
	Limited AI expertise in the	0.0010	0.3980	H_1	6
	construction industry	(Yes)	(Strong)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.3930	H_1	5
	- Unauthorized access to personal information	(Yes)	(Strong)		
	Sluggish electrical service	0.0020	0.3030	H_1	1
	- Too reliable supply	(Yes)	(Strong)		
	Validation and acceptance of AI	0.0010	0.3690	H_1	4
Human	- Lack of knowledges on AI	(Yes)	(Strong)		
Intervention	Greater starting investment required	0.0010	0.3660	H_1	3
- Save costs	for AI	(Yes)	(Strong)		

	- Invest more maintenance				
	Empowerment	0.0010	0.3590	H_1	2
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.4140	H_1	8
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4500	H_1	9
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.5910	H_1	10
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.4110	H_1	7
	- Increased unemployment	(Yes)	(Strong)		
	Limited AI expertise in the	0.0010	0.4630	H_1	6
	construction industry	(Yes)	(Strong)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.4380	H_1	4
	- Unauthorized access to personal information	(Yes)	(Weak)		
	Sluggish electrical service	0.0010	0.4300	H_1	3
	- Too reliable supply	(Yes)	(Strong)		
	Validation and acceptance of AI	0.0010	0.4180	H_1	1
	- Lack of knowledges on AI	(Yes)	(Strong)		
	Greater starting investment required	0.0010	0.4740	H_1	7
	for AI	(Yes)	(Strong)		
	- Invest more maintenance				
Excessive	Empowerment	0.0010	0.4610	H_1	5
Spending	- Lack of training data	(Yes)	(Strong)		
- Increasing	Confronting Cultural	0.0010	0.4190	H_1	2
profit margins	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.5230	H_1	8
	- Potential be used for harmful purposes	(Yes)	(Weak)		
	Occurs in a Complex and Dynamic	0.0010	0.6880	H_1	10
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.6300	H_1	9
	- Increased unemployment	(Yes)	(Weak)		
	Limited AI expertise in the	0.0010	0.5070	H_1	6
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
	Risks of privacy violation	0.0030	0.2960	H_1	1
	- Unauthorized access to personal information	(Yes)	(Strong)		
	Sluggish electrical service	0.0010	0.3490	H_1	2
Excessive	- Too reliable supply	(Yes)	(Strong)		
Spending	Validation and acceptance of AI	0.0010	0.4620	H_1	5
- Increasing	- Lack of knowledges on AI	(Yes)	(Strong)		
revenue	Greater starting investment required	0.0010	0.4100	H_1	4
	for AI	(Yes)	(Strong)		
	- Invest more maintenance				
	Empowerment	0.0010	0.5150	H_1	7
	- Lack of training data	(Yes)	(Weak)		
	Confronting Cultural	0.0010	0.3610	H_1	3
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4190	H_1	5
	- Potential be used for harmful purposes	(Yes)	(Strong)		
	Occurs in a Complex and Dynamic	0.0010	0.6210	H_1	10
	Environment	(Yes)	(Weak)		

	- Navigating the complexities Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.5450 (Weak)	H_1	9
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.5350 (Weak)	H_1	9
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.4350 (Strong)	H_1	7
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.3390 (Strong)	H_1	2
Excessive Spending - Reduced expenditures	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.3590 (Strong)	H_1	4
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.3830 (Strong)	H_1	5
	Empowerment - Lack of training data	0.0010 (Yes)	0.3490 (Strong)	H_1	3
	Confronting Cultural - Still use traditional techniques	0.0010 (Yes)	0.3120 (Strong)	H_1	1
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.4140 (Strong)	H_1	6
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.5200 (Weak)	H_1	8
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.5950 (Strong)	H_1	10
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.7080 (Weak)	H_1	10
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.4770 (Strong)	H_1	5
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.4770 (Strong)	H_1	5
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.4600 (Strong)	H_1	4
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.5310 (Weak)	H_1	8
	Empowerment - Lack of training data	0.0010 (Yes)	0.4290 (Strong)	H_1	3
	Confronting Cultural - Still use traditional techniques	0.0010 (Yes)	0.3290 (Strong)	H_1	1
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.5490 (Weak)	H_1	9
Organization Culture - Connection with technologies	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.4260 (Strong)	H_1	2
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.5070 (Weak)	H_1	7
	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.6470 (Weak)	H_1	10
	Risks of privacy violation - Unauthorized access to personal information	0.0010 (Yes)	0.3870 (Strong)	H_1	2
	Sluggish electrical service	0.0010	0.4170	H_1	3

	- Too reliable supply	(Yes)	(Strong)		
	Validation and acceptance of AI	0.0010	0.4570	H_1	5
Organization	- Lack of knowledges on AI	(Yes)	(Strong)		
Culture	Greater starting investment required	0.0010	0.4230	H_1	4
- Encourages a	for AI	(Yes)	(Strong)		
collective goal	- Invest more maintenance				
	Empowerment	0.0010	0.4930	H_1	8
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.3470	H_1	1
	- Still use traditional techniques	(Yes)	(Strong)		
	Legal Concerns Difficulties	0.0010	0.4830	H_1	7
	- Potential be used for harmful	(Yes)	(Strong)		
	purposes				
	Occurs in a Complex and Dynamic	0.0010	0.5140	H_1	9
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0010	0.4670	H_1	6
	- Increased unemployment	(Yes)	(Strong)		
	Limited AI expertise in the	0.0010	0.3750	H_1	6
	construction industry	(Yes)	(Strong)		
	- Invest more money for training				
	Risks of privacy violation	0.0030	0.2950	H_1	2
	- Unauthorized access to personal	(Yes)	(Strong)		
Organization	information				
Culture	Sluggish electrical service	0.0530	0.2460	H_0	-
- Overcome	- Too reliable supply	(No)	(Strong)		
anticipated	Validation and acceptance of AI	0.0010	0.3320	H_1	4
team anxiety	- Lack of knowledges on AI	(Yes)	(Strong)		
	Greater starting investment required	0.0010	0.3350	H_1	5
	for AI	(Yes)	(Strong)		
	- Invest more maintenance				
	Empowerment	0.0010	0.2910	H_1	1
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0570	0.2670	H_0	-
	- Still use traditional techniques	(No)	(Strong)		
	Legal Concerns Difficulties	0.0570	0.3420	H_0	-
	- Potential be used for harmful	(No)	(Strong)		
	purposes				
	Occurs in a Complex and Dynamic	0.0010	0.5390	H_1	7
	Environment	(Yes)	(Weak)		
	- Navigating the complexities				
	Increasing Deployment	0.0020	0.3070	H_1	3
	- Increased unemployment	(Yes)	(Strong)		
	Limited AI expertise in the	0.0010	0.5240	H_1	9
	construction industry	(Yes)	(Weak)		
	- Invest more money for training				
	Risks of privacy violation	0.0010	0.4490	H_1	6
	- Unauthorized access to personal	(Yes)	(Strong)		
Return on	information				
Investment	Sluggish electrical service	0.0010	0.3990	H_1	4
- Reduction in	- Too reliable supply	(Yes)	(Strong)		
expenses	Validation and acceptance of AI	0.0010	0.4620	H_1	7
	- Lack of knowledges on AI	(Yes)	(Strong)		
	Greater starting investment required	0.0010	0.4620	H_1	7
	for AI	(Yes)	(Strong)		
	- Invest more maintenance				
	Empowerment	0.0010	0.3570	H_1	1
	- Lack of training data	(Yes)	(Strong)		
	Confronting Cultural	0.0010	0.4360	H_1	5
	- Still use traditional techniques	(Yes)	(Strong)		

	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.3850 (Strong)	H_1	3
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.6000 (Weak)	H_1	10
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.3780 (Strong)	H_1	2
Return on Investment - Satisfactory on income	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.4470 (Strong)	H_1	5
	Risks of privacy violation - Unauthorized access to personal information	0.0550 (No)	0.2790 (Strong)	H_0	-
	Sluggish electrical service - Too reliable supply	0.0040 (Yes)	0.2840 (Strong)	H_1	1
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.3610 (Strong)	H_1	2
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.4340 (Strong)	H_1	4
	Empowerment - Lack of training data	0.0540 (No)	0.2430 (Strong)	H_0	-
	Confronting Cultural - Still use traditional techniques	0.0010 (Yes)	0.4110 (Strong)	H_1	3
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0570 (No)	0.2670 (Strong)	H_0	-
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.0010 (Yes)	0.4570 (Strong)	H_1	6
	Increasing Deployment - Increased unemployment	0.0580 (No)	0.2640 (Strong)	H_0	-
Return on Investment - Efficient practices	Limited AI expertise in the construction industry - Invest more money for training	0.0010 (Yes)	0.5810 (Weak)	H_1	8
	Risks of privacy violation - Unauthorized access to personal information	0.5170 (No)	0.2380 (Strong)	H_0	-
	Sluggish electrical service - Too reliable supply	0.0010 (Yes)	0.4000 (Strong)	H_1	4
	Validation and acceptance of AI - Lack of knowledges on AI	0.0010 (Yes)	0.3530 (Strong)	H_1	1
	Greater starting investment required for AI - Invest more maintenance	0.0010 (Yes)	0.4470 (Strong)	H_1	6
	Empowerment - Lack of training data	0.0010 (Yes)	0.4180 (Strong)	H_1	5
	Confronting Cultural - Still use traditional techniques	0.5140 (No)	0.2450 (Strong)	H_0	-
	Legal Concerns Difficulties - Potential be used for harmful purposes	0.0010 (Yes)	0.3680 (Strong)	H_1	2
	Occurs in a Complex and Dynamic Environment - Navigating the complexities	0.010 (Yes)	0.5460 (Weak)	H_1	7
	Increasing Deployment - Increased unemployment	0.0010 (Yes)	0.3920 (Strong)	H_1	3

According to the research that was stated, it has been shown that there has been no research into the relationship between influencing factors and the challenges that are intended to improve construction site workflow performance. Objective 3, which is to analyze the strength of relationship between influencing factors in the use of AI with AI challenges in improving construction site workflow performance, has been completed by the researchers. No study has yet been conducted that analyzes the relationship between the issues. Aside from that, researcher concludes that not all of the criteria have a correlation with the issues that have been presented as shown in Appendix C.

5. Conclusion and Recommendations

5.1 Result and Discussion

The main purpose of this study was to systematically investigate and accomplish the three predetermined objectives that were identified and set forth at the inception of the research effort. These objectives were carefully formulated to guide the research process and ensure the successful attainment of the desired outcomes. According to the predetermined objectives, both the recommendations and the findings will be thoroughly examined and taken into consideration. A few Proposals statement solution for problems are as follows;

i. To enable contractors to engage in this AI practice, it is essential that pertinent authorities in Malaysia, such as the CIDB, focus their endeavors on formulating a comprehensive guideline that delineates the prerequisites they need to meet.
ii. The authorities have the responsibility of ensuring that personnel on building sites adhere to the standards and legislation that regulate artificial intelligence construction approaches.
iii. To guarantee the successful implementation of AI on building sites, it is essential for the pertinent authorities to acquire further state-of-the-art technology from affluent countries.

The present study has yielded results that indicate the successful attainment of all the stated research objectives. This accomplishment has been made possible through the effective utilization of the data analysis outcomes derived from the questionnaires that were completely filled out and returned by the participants. The successful attainment of the objectives is of utmost importance in ensuring the overall success and efficacy of the research effort. Based on the extensive body of research conducted in this field, the diligent researcher has successfully identified and documented the various influencing factors and primary challenges that significantly impact the improvement of construction site workflow performance. It is noteworthy to mention that these findings have been completely acknowledged and agreed upon by a group of Grade 7 contractors, who possess substantial expertise and experience in the construction industry. The previously mentioned problems can be effectively resolved through the implementation of the proposed strategies. This statement effectively underscores the critical significance of implementing artificial intelligence (AI) within the construction site in the present era. Due to its relatively recent emergence in the realm of construction, there exists an obvious need for guidance, incentives, and methodologies to effectively manage and exercise sound judgment in this domain. In light of the findings presented in this research, it can be inferred that there is an optimistic expectation that the relevant stakeholders and individuals tasked with addressing the identified issues will undertake effective measures and employ successful strategies to tackle them. The construction industry possesses the inherent capacity to attain higher standards of prosperity and achievement if it is executed in such a manner.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nurul Azreen Izzatie Roslan, Rozlin Zainal;* ***data collection:*** *Nurul Azreen Izzatie Roslan;* ***analysis and interpretation of results:*** *Nurul Azreen Izzatie Roslan;* ***draft manuscript preparation:*** *Nurul Azreen Izzatie Roslan, Rozlin Zainal, Mohd Hilmi Izwan Abd Rahim, Narimah Kasim. All authors reviewed the results and approved the final version of the manuscript.*

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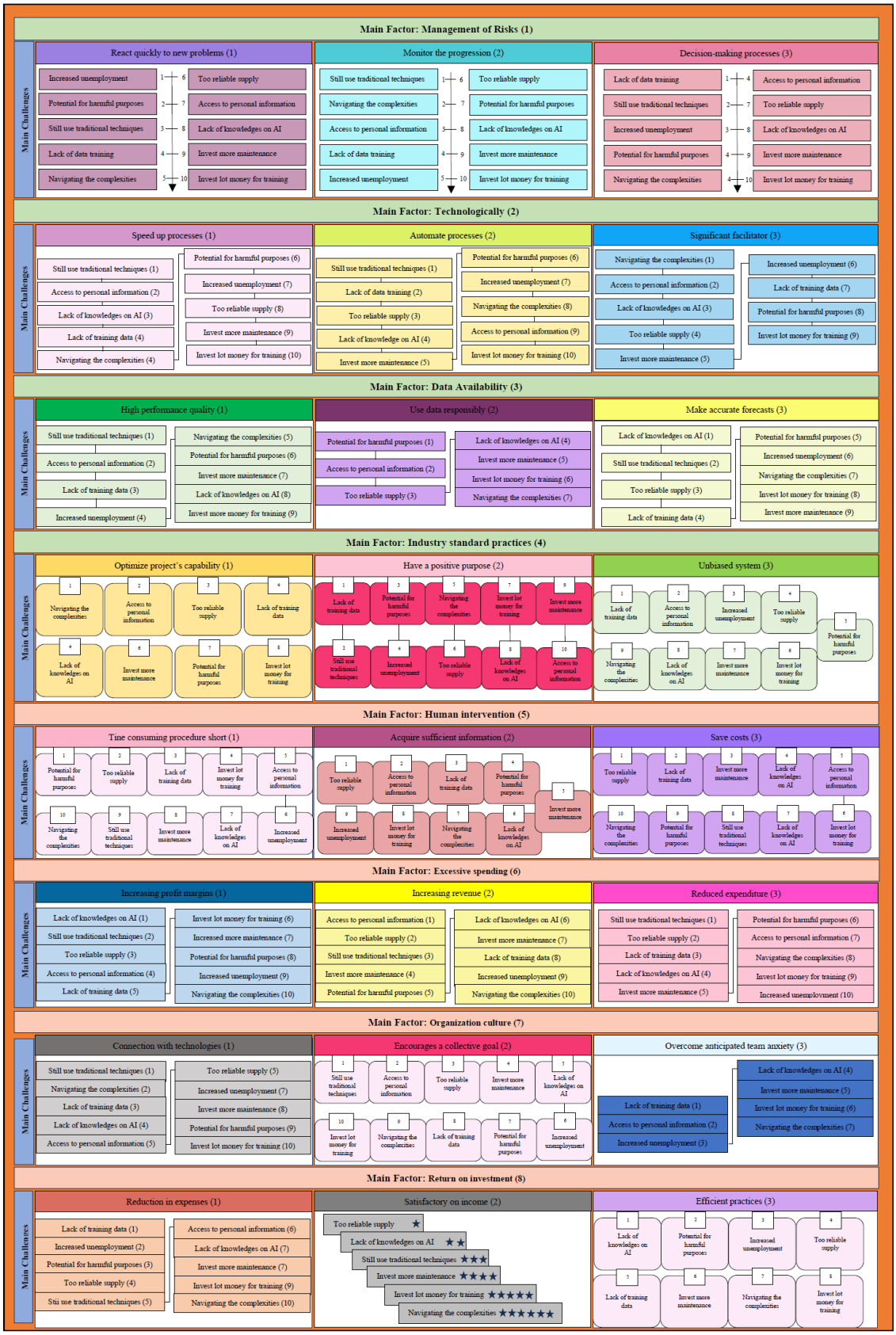
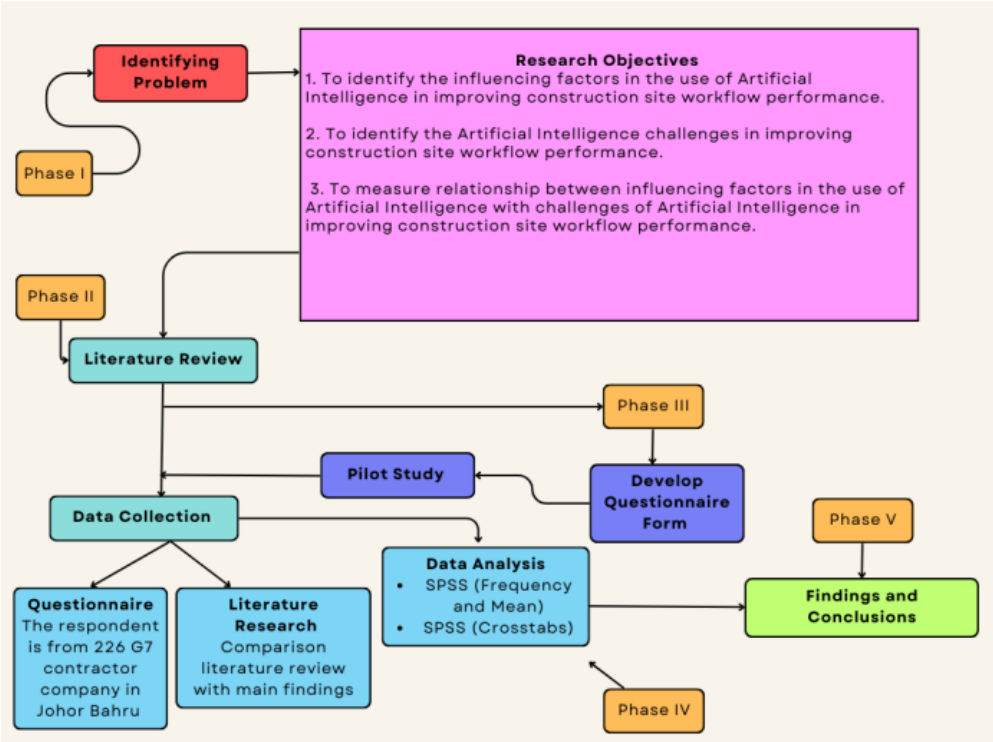


Fig 1 *Relationship Framework for main influencing factors in the use of AI with main AI challenges in improving construction site workflow performance.*

APPENDIX A: Procedure of Research



APPENDIX B: Table Population (N) and sample (S) Krejcie and Morgan

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970

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APPENDIX C: Relationship Analysis for Main Influencing Factors in the Use of AI with Main Challenges in Improving Construction Site Workflow Performance

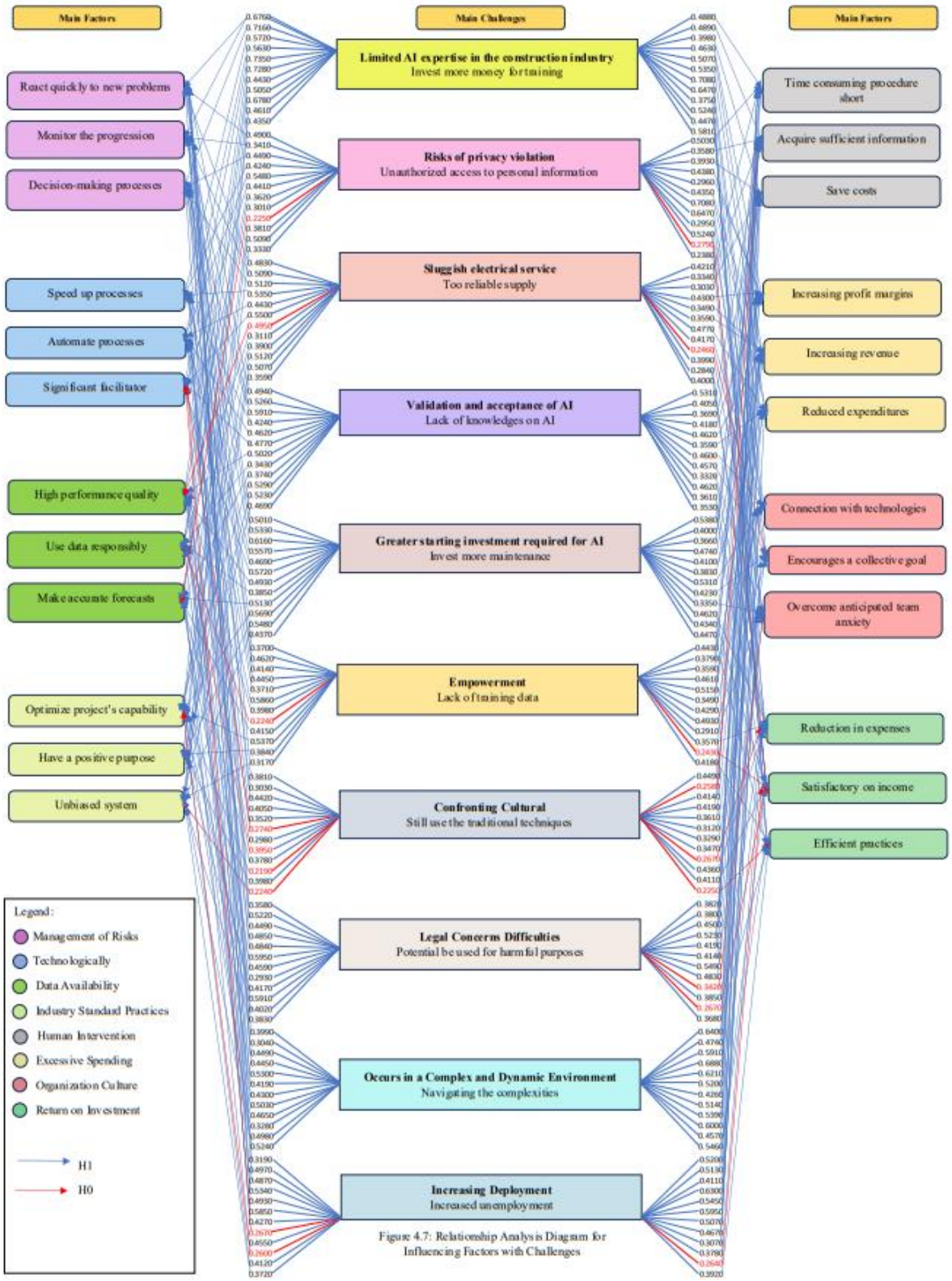

Figure 4.7: Relationship Analysis Diagram for Influencing Factors with Challenges

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