

Integrating Artificial Intelligence and Human Decision-Making to Enhance Risk Management Effectiveness in Construction Projects

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ABSTRACT

The complexity of construction projects leads to increased uncertainty and risks that require a more effective risk management approach. The integration of Artificial Intelligence (AI) and human decision-making is a potential strategy to improve project risk identification, analysis, and mitigation capabilities. This study aims to analyze the influence of AI and human decision-making integration on the effectiveness of risk management in construction projects. The study used a quantitative approach through a survey of 100 construction practitioners with a data collection technique in the form of a questionnaire. Data were analyzed using multiple linear regression to test the relationships between variables. The results show that the integration of AI and the quality of human decision-making has a positive effect on the effectiveness of construction risk management. This research makes a practical contribution to the development of technology-based risk management strategies while maintaining the role of humans in the decision-making process.

INTRODUCTION

The construction industry is a sector that has a high level of complexity and uncertainty because it involves many stakeholders, large resource use, changes in environmental conditions, and demands for project completion according to the target cost, time, and quality. Construction risks such as project delays, cost overruns, work accidents, coordination failures, and supply chain disruptions are still major problems in the success of the project. Changing global business environments and increasing project complexity have led to conventional risk management approaches that rely on individual experience often face limitations in making rapid risk predictions and responses. Shishehgarkhaneh et al. (2024) explain that construction risk management increasingly requires a data-driven approach to deal with various categories of risks that arise in the project life cycle, especially in the supply chain and strategic decision-making aspects.

The development of digital technology in the Industry 4.0 era has encouraged the application of Artificial Intelligence (AI) as a new approach in improving construction management capabilities. AI through technologies such as machine learning, natural language processing, computer vision, and predictive analytics has the ability to process large amounts of data, recognize risk patterns, and provide predictive information to support project decisions. Tian et al. (2025) through a systematic literature review of AI research in construction risk management shows that AI has been widely applied for risk identification, delay prediction, cost control, work safety, and project risk evaluation. However, the application of AI in construction has to do not only with the capabilities of algorithms, but also with how the information generated can be used effectively by humans in the decision-making process.

Although previous research has shown the benefits of AI in improving risk analysis capabilities, there is still a research gap regarding how integration between AI and human decision-making can improve overall risk management effectiveness. Most previous research has focused more on the technical aspects of developing prediction models and improving the accuracy of algorithms, while human factors as users, interpretation of analysis results, and final decision-makers have received less attention. Gao et al. (2026) stated that AI research in construction management still faces challenges in terms of organizational implementation, user readiness, and integration between technology and human decision-making processes. This shows that the success of AI is not only determined by technological sophistication, but also by the ability of humans to understand and utilize the results of AI analysis appropriately.

In addition to limitations on the human aspect, the application of AI in construction risk management also faces various challenges such as data quality, algorithm transparency, user trust, and the potential for misinterpretation of prediction results. Wuni (2025) identified that the application of AI in construction projects has various risks related to technical, management, knowledge, and decision-making aspects. The research confirms that a socio-technical approach that combines technological capabilities and human capacity is still needed to produce a more effective risk management system. Thus, research on the relationship between AI integration and human decision-making is important to understand how technology can strengthen, rather than replace, the role of construction professionals in the face of project uncertainty.

Based on the problems and gaps in the research, this study aims to analyze the influence of the integration of Artificial Intelligence and human decision-making on the effectiveness of risk management in construction projects. This research focuses on the relationship between the use of AI as a tool to support risk analysis, human ability to evaluate and make decisions based on this information, and its impact on the effectiveness of project risk identification, analysis, and mitigation processes. An empirical approach through a survey of construction practitioners was used to gain an understanding of how the combination of technological and human factors contributes to improved risk management performance.

This research makes a theoretical contribution by expanding the perspective of construction management through a socio-technical approach that places AI and humans as two complementary elements in project risk management. In practice, this study provides recommendations for construction companies in implementing AI technology more effectively through strengthening human resource competencies and improving the quality of decision-making processes. By understanding the relationship between AI and human decision-making, construction organizations can develop risk management strategies that are more adaptive, data-driven, and capable of dealing with the complexities of modern projects.

LITERATURE REVIEW

Artificial Intelligence in Construction Project Risk Management

Risk management is an essential element in the success of a construction project because projects are complex, dynamic, and full of uncertainty. Conventional approaches to risk management generally still rely on project managers' experience and manual evaluations, so they have limitations in processing large and complex data. The development of Artificial Intelligence (AI) provides new opportunities through predictive analysis capabilities, pattern recognition, and real-time data processing to support the process of identifying and mitigating construction project risks.

AI in construction has been applied through various technologies such as machine learning, deep learning, natural language processing (NLP), and computer vision. The technology is able to help construction organizations predict possible project failures, detect safety risks, and improve the accuracy of data-driven decision-making. According to Darko et al. (2023), the application of AI in the construction industry has evolved from just job automation to a decision support system that is able to improve the efficiency and quality of project management. AI allows project managers to obtain risk information early so that mitigation actions can be taken proactively.

Nevertheless, the effectiveness of AI in risk management is not only determined by its technological capabilities, but also by how the organization is able to integrate AI into its work processes and decision-making. Tian et al. (2025) explain that although AI has a high ability to predict risks, challenges such as data quality, model interpretation limitations, and user readiness are still obstacles to the optimal application of AI in construction projects.

Human Decision-Making in Construction Risk Management

While AI technology is capable of providing data-driven analysis, the final decision in a construction project still requires human involvement. Human decision-making plays an important role because construction risks are often influenced by contextual factors such as field conditions, relationships between project actors, regulations, and professional experience that algorithms cannot always understand. According to Abioye et al. (2021), the successful application of digital technology in construction is greatly influenced by the ability of humans to understand, evaluate, and use the information generated by technology. In the context of risk management, professional experience and competence allow project managers to interpret the results of AI analysis and determine mitigation strategies that are appropriate to the actual conditions of the project.

Research by Nyqvist et al. (2024) shows that generative AI such as ChatGPT is capable of generating broad and systematic risk identification, but still has limitations in providing recommendations specific to specific project conditions. This shows that AI analytical capabilities need to be combined with human knowledge so that risk decisions become more realistic and actionable. Thus, human decision-making is not an alternative to AI, but a component that strengthens the effectiveness of the technology.

Integration of Artificial Intelligence and Human Decision-Making as a Socio-Technical Approach

The integration between AI and humans in construction management can be understood through a socio-technical perspective, which is an approach that sees technology and humans as systems that interact with each other. In this approach, AI functions to provide data-driven information, while humans play a role in providing interpretation, considering non-technical factors, and making strategic decisions.

According to Pan and Zhang (2021), the development of AI technology in construction needs to be directed at the concept of human-centered artificial intelligence, which is the use of AI to improve human capabilities, rather than replacing the role of humans completely. The approach is relevant in risk management because project decisions often require a combination of quantitative analysis and experiential considerations.

Furthermore, Cheng et al. (2024) stated that human collaboration and AI can improve the quality of decisions in complex project environments through improved predictive capabilities, reduced decision bias, and accelerated response to changing project conditions. Therefore, the integration of AI and human decision-making is expected to have a positive relationship with the effectiveness of construction risk management.

Effectiveness of Risk Management in Construction Projects

Construction risk management effectiveness describes the ability of a project organization to systematically identify, analyze, respond, and control risks to achieve project objectives. Effective risk management can reduce the possibility of delays, cost overruns, and project quality failures. According to Olawumi and Chan (2022), the success of risk management in construction projects is influenced by the organization's ability to obtain accurate information, conduct rapid risk evaluations, and implement appropriate mitigation strategies. The use of digital technologies such as AI provides opportunities to improve the quality of these processes through the provision of predictive information and data-driven analysis.

Thus, the effectiveness of risk management depends not only on the existence of technology, but also on the ability of organizations to integrate such technology with human competence. The combination of AI and human decisions is a potential approach to improve the project's ability to deal with uncertainty.

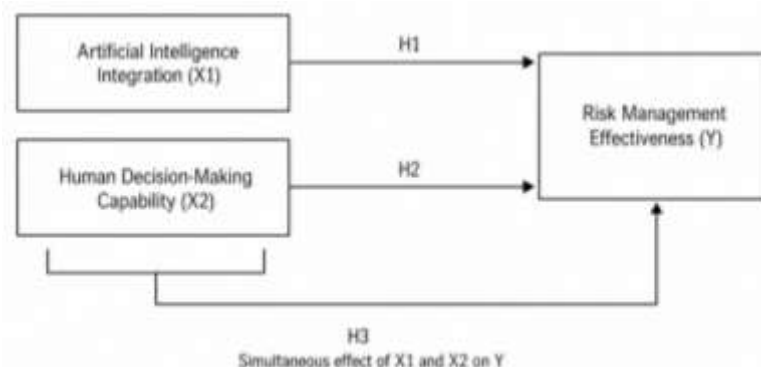


Figure 1. Research Hypothesis Model

METHODOLOGY

Types of Research

This study uses a quantitative approach with an explanatory research design to analyze the influence of the integration of Artificial Intelligence (AI) and human decision-making on the effectiveness of risk management in construction projects. This study examines the relationship between Artificial Intelligence Integration (X1) and Human Decision-Making Capability (X2) on Risk Management Effectiveness (Y) using multiple linear regression analysis.

The research model is formulated as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + e$$

This approach is used to measure the relationship between variables empirically based on the data of construction practitioner respondents.

Population and Sample

The research population is construction project practitioners involved in the risk management process, including project managers, construction managers, site engineers, supervisors, and quantity surveyors. The number of research respondents was 100 construction practitioners. The selection of respondents was carried out because the group had first-hand experience in decision-making and project risk management.

Research Instruments

Data collection was carried out using a closed questionnaire with a Likert scale of 1–5 (1 = strongly disagree to 5 = strongly agree). The research instrument consists of three variables with 15 indicators, namely Artificial Intelligence Integration (X1) which measures the use of AI in risk management, Human Decision-Making Capability (X2) which measures decision-making ability, and Risk Management Effectiveness (Y) which measures the effectiveness of risk management of construction projects. The validity of the instrument was tested using the Pearson Product Moment, with a correlation value criterion of > 0.30. Reliability was tested using Cronbach's Alpha, with a value of $\alpha > 0.70$ indicating a reliable instrument (Hair et al., 2022).

Data Collection Procedure

The research was carried out through several stages, namely literature study, instrument preparation, distribution of questionnaires to respondents, data collection, and statistical processing and analysis. The data used is primary data obtained directly from construction practitioners through questionnaires.

Data Analysis Techniques

Data analysis was carried out using IBM SPSS Statistics through descriptive analysis, instrument validity and reliability testing, and classical assumption tests that included normality, multicollinearity, and heteroscedasticity. Furthermore, multiple linear regression was used to test the influence of Artificial Intelligence Integration (X1) and Human Decision-Making Capability (X2) on Risk Management Effectiveness (Y). Hypothesis testing was carried out using a t-test for partial influence, an F test for simultaneous influence, and a determination coefficient (R^2) to determine the model's ability to explain variations in risk management effectiveness.

RESEARCH RESULT

Characteristics of Respondents

This study involved 100 respondents who were construction practitioners who had experience in project management and risk management processes. Respondents' characteristics included job title, work experience, education level, and the type of project they had handled.

Table 1. Characteristics of Respondents

Features	Category	Frequency	Percentage (%)
Departments	Project Manager	18	18
	Construction Manager	20	20
	Site Engineer	32	32
	Supervisor	20	20
	Quantity Surveyor	10	10
Total		100	100
Work Experience	2-5 years	34	34
	6-10 years	42	42
	>10 years	24	24
Total		100	100
Education	Diploma	22	22
	Bachelor (S1)	68	68
	Postgraduate (S2)	10	10
Total		100	100
Project Type	Gedung	38	38
	Road/Bridge Infrastructure	35	35
	Industry	17	17
	Others	10	10
Total		100	100

Descriptive Statistics of Research Variables

The results of the descriptive analysis showed that all research variables had an average value in the high category. The Artificial Intelligence Integration variable obtained an average score of 4.12, Human Decision-Making Capability of 4.25, and Risk Management Effectiveness of 4.21.

Table 2. Descriptive Statistics

Variabel	Minimum	Maximum	Mean	Standard Deviation
Artificial Intelligence Integration (X1)	2,40	5,00	4,12	0,56
Human Decision-Making Capability (X2)	2,80	5,00	4,25	0,51
Risk Management Effectiveness (Y)	2,60	5,00	4,21	0,54

Validity and Reliability Test Results

Validity testing was carried out on all research indicators using item-total correlation values. The test results show that all indicators have a correlation value greater than 0.30 so that all items are declared valid.

Table 3. Validity Test Results

Variabel	Number of Items	Range r-count	Status
Artificial Intelligence Integration (X1)	5	0,612–0,824	Valid
Human Decision-Making Capability (X2)	5	0,645–0,851	Valid
Risk Management Effectiveness (Y)	5	0,631–0,839	Valid

The results of the reliability test using Cronbach's Alpha showed that all variables had values greater than 0.70.

Table 4. Reliability Test Results

Variabel	Cronbach's Alpha	Status
Artificial Intelligence Integration (X1)	0,861	Reliable
Human Decision-Making Capability (X2)	0,884	Reliable
Risk Management Effectiveness (Y)	0,872	Reliable

Regression Analysis Results

Multiple linear regression analysis was performed to determine the influence of Artificial Intelligence Integration (X1) and Human Decision-Making Capability (X2) on Risk Management Effectiveness (Y).

The regression model obtained is:

Table 5. Multiple Linear Regression Results

Independent Variables	Coeficin β	t-value	Say.
Constant	0,842	-	-
Artificial Intelligence Integration (X1)	0,356	4,672	0,000
Human Decision-Making Capability (X2)	0,421	5,384	0,000

Hypothesis Testing Results

Hypothesis testing was carried out using partial (t-test) and simultaneous (F-test) tests.

Table 6. Hypothesis Testing Results

Hipotesis	Variable Relationships	Results	Verdict
H1	Artificial Intelligence Integration → Risk Management Effectiveness	$\beta = 0,356$; $p < 0,05$	Supported
H2	Human Decision-Making Capability → Risk Management Effectiveness	$\beta = 0,421$; $p < 0,05$	Supported
H3	X1 and X2 simultaneously → Risk Management Effectiveness	$F = 48,621$; $p < 0,001$	Supported

Model Fit and Variance Explained

The results of the analysis show that the variables Artificial Intelligence Integration and Human Decision-Making Capability together are able to explain the variation in Risk Management Effectiveness.

Table 7. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error
Regression Model	0,708	0,501	0,491	0,382

The results showed that the research model had the ability to explain 50.1% of the variation in the effectiveness of construction risk management, while 49.9% was influenced by other factors outside the research model.

Summary of Main Findings

The results show that the integration of Artificial Intelligence and human decision-making capabilities has a positive relationship with the effectiveness of risk management in construction projects. The Artificial Intelligence Integration variable was proven to have a positive and significant influence on Risk Management Effectiveness, with a regression coefficient value of 0.356 ($p < 0.05$), which shows that increasing the use of AI in the process of identifying, analyzing, and predicting risks can increase the effectiveness of project risk management. In addition, the Human Decision-Making Capability variable also showed a positive and significant influence on the effectiveness of risk management with a regression coefficient of 0.421 ($p < 0.05$), which shows that the ability of construction professionals to understand information, evaluate project conditions, and determine mitigation strategies has an important contribution to the success of risk management.

Simultaneously, the test results showed that the combination of Artificial Intelligence Integration and Human Decision-Making Capability had a significant effect on Risk Management Effectiveness with an F value of 48.621 ($p < 0.001$). The research model was able to explain the 50.1% variation in the effectiveness of construction risk management based on the value of the determination coefficient ($R^2 = 0.501$). These findings show that the application of AI technology combined with human decision-making capabilities is an

important factor in improving the process of identification, evaluation, and risk mitigation in construction projects.

DISCUSSION

The results showed that Artificial Intelligence Integration (X1) had a positive and significant effect on Risk Management Effectiveness (Y) with a regression coefficient value of 0.356 ($p < 0.05$). These findings show that the increased use of AI in the process of identifying, analyzing, predicting, and evaluating risks is able to improve the effectiveness of construction project risk management. In the context of modern construction management, AI serves as a decision support system that allows organizations to process project data more quickly, recognize risk patterns, and generate predictive information that supports mitigation actions. These results are in line with the concept of data-driven risk management, where risk decisions rely not only on historical experience, but also on the ability of technology to provide data-driven information. Previous research shows that AI has developed into a strategic tool in construction risk management through the application of machine learning, natural language processing, and computer vision to support project risk identification and evaluation. The findings of this study reinforce previous research, but at the same time expand the study by demonstrating the empirical impact of AI on the effectiveness of risk management through the perspective of users at the project level.

The positive influence of AI on the effectiveness of risk management also shows that technology does not only play a role as an automation tool, but also as a mechanism to improve organizational capabilities in the face of project uncertainty. Construction projects have complex characteristics with changing field conditions, limited information, and various interconnected sources of risk. In these conditions, AI's ability to analyze historical data as well as actual data can help project management respond to risks more proactively. However, the results of this study also show that the implementation of AI must be understood as part of an organizational system, not just as a technology investment. This supports the findings of Ghanbaripour et al. (2025) that although AI has high capabilities in the construction risk management cycle, barriers such as data quality, limitations of system adaptation, and organizational resistance are still factors that determine the success of AI deployment. Thus, this study answers the previous research gap that focused more on the technical capabilities of AI algorithms than on how AI provides real value in the risk decision-making process.

In addition, the study found that Human Decision-Making Capability (X2) had a positive and significant influence on Risk Management Effectiveness (Y) with a regression coefficient value of 0.421 ($p < 0.05$). The greater value of the coefficient than AI shows that the human factor is still the dominant element in the effectiveness of construction risk management. These results show that professional experience, the ability to understand project conditions, and the ability to evaluate information are important factors in determining the quality of risk decisions. These findings support the human-centered artificial intelligence approach, which explains that AI technology should improve human

decision-making capabilities, not replace human functions entirely (Pan & Zhang, 2021). In construction projects, many risk decisions require contextual considerations that algorithms can't always understand, such as the conditions of relationships between project actors, changes in the work environment, and other external factors.

The findings related to the dominance of human roles also reinforce the results of previous research on the limitations of AI in understanding the specific context of the project. Nyqvist et al. (2024) explain that although generative AI is able to help the process of systematically identifying risks, the results of the analysis still require human evaluation to match the real conditions of the project. Therefore, the results of this study contribute to the development of construction management science by affirming that the effectiveness of risk management is not only determined by the level of technology adoption, but also by the organization's ability to build collaboration between technology and human competence. These findings differ from some previous studies that tend to view AI as the main solution to construction risk problems. Instead, the study shows that the success of AI is highly dependent on the ability of humans to interpret and use the information generated by AI systems.

Simultaneous testing showed that the combination of Artificial Intelligence Integration and Human Decision-Making Capability had a significant effect on Risk Management Effectiveness with an F value of 48.621 ($p < 0.001$), and was able to explain the 50.1% variation in risk management effectiveness based on the value of $R^2 = 0.501$. These results show that a collaborative approach between AI analytics capabilities and human decision-making capabilities is a more effective model than an approach that relies solely on technology or individual experience. These findings support a socio-technical perspective that states that the success of digital transformation in an organization depends on a balance between technological systems and human factors. Cheng et al. (2024) also show that human and AI collaboration can improve the quality of decisions in complex environments through improved predictive capabilities, reduced decision bias, and accelerated response to changing project conditions.

Theoretically, this research contributes by expanding the understanding of the relationship between AI technology and human factors in the context of construction risk management. Previous research has largely focused on developing AI-based prediction models, while this study adds an implementation perspective by examining how AI and human decision-making capabilities together affect the effectiveness of project risks. In practical terms, the results show that it is not enough for construction companies to adopt AI technology, but also need to improve human resource competencies through training, digital literacy improvement, and the development of a data-driven decision-making culture. This approach can help construction organizations get the most out of AI while maintaining the professional considerations that are still needed in risk management.

Although the study provides relevant findings, there are some limitations to be noted. First, the study uses a quantitative approach based on respondent perceptions so that it does not fully describe how AI is used in the risk process under real project conditions. Second, the research respondents only came from a group of construction practitioners with a total of 100 people, so the generalization of the results is still limited to the context of this study. In addition, the research has not included other factors such as the quality of AI data, organizational readiness, digital culture, and the level of user trust in the technology. Further research can develop a mixed method approach or project case study to understand the mechanisms of human interaction and AI more deeply and develop a more adaptive and contextual AI-based construction risk management model.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that the integration of Artificial Intelligence and Human Decision-Making Capability has an important role in increasing the effectiveness of risk management in construction projects. The results of the analysis show that Artificial Intelligence Integration has a positive and significant effect on Risk Management Effectiveness, which shows that the use of AI in risk identification, analysis, and prediction is able to improve the quality of the project risk management process. In addition, Human Decision-Making Capability also provides a stronger positive influence, showing that professional experience, information interpretation ability, and human judgment remain important factors in making informed risk decisions. Simultaneously, the combination of AI and human capabilities has been proven to increase the effectiveness of construction risk management, making a collaborative approach between technology and humans a relevant strategy in dealing with the complexity of modern projects.

Based on these findings, the study recommends that construction companies not only focus on investing in AI technology, but also improve organizational readiness through digital competency development, training in the use of AI systems, and strengthening data-driven decision-making capabilities. AI implementation needs to be directed as a decision-support tool that strengthens the role of construction professionals, rather than replacing human involvement in strategic processes. Further research is suggested to expand the research model to include other factors such as organizational readiness, quality of AI data, user trust in technology, and corporate digital culture. In addition, a mixed method approach or real project case studies can be used to gain a deeper understanding of the mechanisms of interaction between AI and humans in construction risk management practices. This recommendation is important because the current study is still using a perception-based quantitative approach with 100 respondents, so exploration of the context of real implementation is still needed.

ADVANCED RESEARCH

Advanced research can develop AI and human decision-making integration models by considering mediation or moderation variables such as AI readiness, organizational capability, data quality, and digital leadership. In addition, the development of machine learning-based models combined with human decision evaluation can provide a more comprehensive understanding of construction risk management optimization in the future.

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