Artificial Intelligence for Enhancing Engineering Project Management During Emergencies: Perception-based Analysis

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ABSTRACT

Purpose: The research studies the impact of various Artificial Intelligence (AI) tools on engineering project management and describes how they affect management success during emergencies in the Ukrainian context. Special attention is paid to the skills comprising AI readiness among engineers and their formation in the system of continuous education.

Methodology/Approach: The study employed a perception-based analysis and applied the social cognitive theory and expectancy theory, enabling structured opinion-based questionnaires on Likert scales and assessing engineering project success after the introduction of AI tools. The research involved 96 engineers with diverse roles and expertise representing civil engineering companies or military organisations.

Findings: The research explained the peculiarities of some challenges hindering engineering project management and defined traditional, agile, and hybrid engineering project management used during emergencies. 25 AI tools were outlined, and their impact on project success was revealed. The category of AI readiness was described, and its components were presented.

Research Limitation/implication: Since the perception-based analysis relies on subjective views, it may not fully present the objective evaluation of AI tools in engineering project management during emergencies. The findings can be used to improve engineers' training programs by integrating AI-focused modules.

Originality/Value of paper: The research provides a context-specific understanding of how AI can be applied to the unique challenges faced in Ukraine.

Category: Research paper

Keywords: AI readiness; AI tools; challenge; engineering project; project success

1 INTRODUCTION

In the 21st century, the era of innovations, an engineering project is a dynamic initiative that integrates cutting-edge technologies and digital tools to solve modern challenges or create new advancements (Taboada, et al., 2023). Engineering projects require effective project management, balancing technical expertise with leadership, risk assessment, communication, and problem-solving to ensure the successful delivery of outcomes (Gepp, et al., 2014; Ciric Lalic, et al., 2022). Engineering project management demands specific attention during emergencies since it faces the significant challenges of natural and man-made disasters (Noran, 2014). Some studies revealed that emergency engineering project management needs to improve the efficiency of rapid response, collaborative and risk-informed decision-making, and flexibility (Zhu, Wang and Li, 2023; Žužek, et al., 2020) to overcome urgent and unexpected conditions. Steen, Haakonsen and Steiro (2023) insist that forming emergency readiness, competence-based training, and exercise activities strengthen resilience characteristics and prepare teams for various scenarios. Generally, emergencies, such as natural disasters, pandemics, and technological accidents, necessitate effective engineering project management (Epstein and Harding, 2020). In Ukraine, the ongoing war affects engineering project management, bringing numerous difficulties that interrupt normal operations (Horobets and Motuzka, 2023).

Zabala-Vargas, Jaimes-Quintanilla and Jimenez-Barrera (2023) indicated that for success, engineering project management depends on integrating intelligent technologies to optimise the procedures; this is particularly true for the projects implemented during emergencies. Intelligent technologies, such as artificial intelligence (AI), data analytics, and automation systems, improve decision-making, reduce costs, facilitate predictive maintenance of equipment, and improve sustainability (Horobets and Motuzka, 2023; Marnewick and Marnewick, 2021). As a result, they contribute to meeting the demands of modern project management practices in the rapidly changing world where emergencies are increasingly prevalent. Because of the subject's importance, this paper suggests investigating the impact of AI-driven tools on engineering project management and presenting innovative solutions for improving the implementation of engineering projects during emergencies.

2 LITERATURE REVIEW

2.1 Conception of engineering project management during emergencies

Engineering project management is a complex multidisciplinary field that is related to engineering, business, and management knowledge to plan, execute and deliver projects effectively (Gepp, et al., 2014). This management is characterised by strong technical expertise, complexity, and integration of various components to ensure the project meets strict industry standards (Lamprou and Vagiona, 2018). Effective risk management is necessary as engineering projects often encounter significant technical challenges and uncertainties (Xue, et al., 2021). According to Nenni, et al. (2024), in the age of digitalisation, engineering projects require the involvement of innovative engineering knowledge to develop effective solutions. Engineering project management focuses on specific improvements to overcome crises during emergencies. Certain outcomes revealed that it deals with rapid response (Zhu, Wang and Li, 2023) and flexibility (Žužek, et al., 2020). Some recent studies Jiang, et al. (2024) indicate that during emergencies, the identification and assessment of risks (Jiang, et al., 2024) and strong interdisciplinary efforts (Noran, 2014) become very important. Besides, certain scholars emphasise the significance of resource optimisation, effective communication, and technological integration (Carreras-Coch, et al., 2022).

The scientific literature differentiates traditional, agile, and hybrid engineering project management that can be introduced during emergencies. The traditional model refers to the systematic use of well-established methodologies and verified practices (Ciric Lalic, et al., 2022). It typically involves linear and consecutive processes, detailed planning, clearly defined roles, and emphasis on documentation (Gemino, Horner Reich and Serrador, 2021). Some findings are devoted to agile engineering project management, characterised by a flexible approach to managing projects, adaptability to change, continuous improvement, and focus on quality (Ciric Lalic, et al., 2022). According to Dong et al. (2024), agile management effectively implements innovative techniques or digital tools; agile teams can rapidly re-prioritise tasks and act dynamically during emergencies. The hybrid model combines traditional and agile elements to create a flexible approach to managing engineering projects. It is found to be beneficial for complex projects that require both a stable framework and the agility to innovate and adjust as the project progresses (Gemino, Horner Reich and Serrador, 2021).

Engineering project management differs depending on the type of project – civil or military. The civil sector focuses on restoring infrastructure, providing essential services, and ensuring public safety (Steen, Haakonsen and Steiro, 2023). Here, flexibility and adaptability are important, as civil sector projects often face unexpected challenges and changing conditions during emergencies. In contrast, engineering project management in the military sector involves a more centralised and hierarchical approach because military engineers operate within a structured command system, prioritising strategic objectives, security, and rapid response. The military emphasises discipline, planning, and efficiency, allowing for swift decision-making (Dajerling, 2023). Therefore, both civil and military engineering project management require innovative digital technologies to enhance efficiency, accuracy, and communication during emergencies.

2.2 AI and engineering project management: benefits and challenges

Currently, a number of findings state that AI is significant for engineering project management (Odejide and Edunjobi, 2024; Zabala-Vargas, Jaimes-Quintanilla and Jimenez-Barrera, 2023). It has begun to radically transform the way projects are planned, managed and executed (Nenni, et al., 2024). AI within engineering project management creates the AI ecosystem integrating advanced technologies that interconnect various project elements (Taboada, et al., 2023). Many studies outline AI-based techniques used in engineering project management (Horobets and Motuzka, 2023; Taboada, et al., 2023), which are the following: Machine Learning; Deep Learning; Natural Language Processing; Autonomous Systems; Image Recognition; Risk Management Software; Chatbots and Virtual Assistants.

AI-based tools contribute to data-driven decisions (Odejide and Edunjobi, 2024) and forecast potential risks or resource requirements (Taboada, et al., 2023). Some findings show that AI improves efficiency by automating routine tasks, enabling continuous project progress monitoring and detecting deviations (Zabala-Vargas, Jaimes-Quintanilla and Jimenez-Barrera, 2023). AI-driven collaborative platforms maintain project team members' interactions, enhancing coordination (Carreras-Coch, et al., 2022). Additionally, AI assists in quality control, adaptive scheduling, risk management, and improved safety; it contributes to proactive planning and enhances emergency response efforts' speed, accuracy, and efficiency (Nenni et al., 2024).

The literature analysis proves that while AI offers significant advantages in engineering project management during emergencies, there are also several potential disadvantages. Mainly, AI systems rely heavily on technology infrastructure (Odejide and Edunjobi, 2024). In extreme situations, the disruptions to these systems hinder their effectiveness and reliability. Taboada, et al. (2023) mention that AI tools require high-quality data to function optimally but during emergencies, accessing accurate and timely data may be challenging. Besides, AI systems are vulnerable to cyber security threats (Nenni, et al., 2024). In this context, AI readiness among engineering project managers refers to their preparedness to integrate and apply AI tools to achieve the success of an engineering project (Chmyr and Bhinder, 2023; Odejide and Edunjobi, 2024).

2.3 Evaluation of engineering project success

The success of engineering projects is interpreted through quantitative and qualitative approaches, where the first one focuses on measurable outcomes while the other one considers the quality of decision-making, organisational culture, and leadership (Lamprou and Vagiona, 2018). In the context of this research, critical factors contributing to engineering project success concern clear objectives, effective communication, skilled and experienced teams, detailed planning, risk and resources management, and quality control (Abu Awwad, Shibani and Ghostin, 2022). Gepp, et al. (2014) differentiated structured scheduling, 'stakeholders' satisfaction, costs, flexibility, and risk management. Sometimes, the factors relate to frequent design changes, inadequate planning, price fluctuations, or a shortage of expert site staff (Zahoor and Ali, 2023).

It becomes evident that critical factors of engineering project success can be divided into some categories. Firstly, Radujković and Sjekavica (2017) describe elements regarding management competencies, organisation, and project management methods, tools and techniques. With a focus on time, the concept of project success was explored across four dimensions: from project execution to immediate post-completion; a medium-term dimension, focusing on project technical specifications; orientation towards organisational performance and sustainability; and future readiness (Zahoor and Ali, 2023). Abu Awwad, Shibani, and Ghostin (2022) offer the classification based on cost, time, quality considerations, management effectiveness, and organisational achievements. Success in engineering projects during the war in Ukraine is characterised by the ability to adapt to changing circumstances rapidly. Importantly, projects that effectively apply technology and innovative solutions demonstrate resilience and enhance efficiency despite challenging conditions (Myronenko, 2023).

Scientific literature showed that critical factors of engineering project success consider specific components related to AI applications (Odejide and Edunjobi, 2024). For instance, engineering project success depends on data-driven decision-making, which reduces reliance on intuition and allows for more accurate strategic planning and risk mitigation. Nenni, et al. (2024) highlighted the importance of algorithmic optimisation, which ensures that project tasks are executed efficiently, minimising delays and maximising productivity. Other critical factors include developing predictive modelling; introducing automation and intelligent systems to streamline repetitive and time-consuming tasks; implementing AI tools to assess project risks, and incorporating uncertainty, variability, and interdependencies (Marnewick and Marnewick, 2021).

Special attention is paid to professional training since well-trained engineers can apply the best practices, use advanced technologies, and provide innovative solutions that meet project requirements. During emergencies, the importance of professional training becomes even more pronounced (Bhinder, 2019). Engineers with high levels of competencies can adapt to unexpected situations and continue delivering high-quality work. ' training requires certain teaching strategies that form technical proficiency and crisis adaptability (Torichnyi and Bhinder, 2019). Besides, AI-based technologies are widely used to simulate real-life scenarios at higher educational institutions (Chmyr and Bhinder, 2023). When training engineers, the curriculum is adapted to emphasise practical, crisis-oriented skills alongside traditional technical knowledge (Moea, 2024). The curriculum integrates specialised modules focusing on risk management (Epstein and Harding, 2020) and suggests using effective outcome-based assessment techniques (Hoang Yen, et al., 2024).

The literature review showed that using AI during emergencies has been insufficiently studied, and scholarly opinions on implementing AI tools to achieve successful project management differ significantly. Therefore, the research aims to present the impact of various AI tools on engineering project management and describe how they affect management success during emergencies. This research seeks to answer the following questions: (1) What challenges do engineering projects face during emergencies? What type of engineering project management is more efficient? (2) How do AI tools affect engineering project success during emergencies? (3) What skills are necessary for engineers to use AI tools during emergencies, and how are they formed in the system of continuous education?

3 METHODOLOGY

The study employed a perception-based analysis to understand and assess participants' subjective views, experiences, and attitudes in engineering project management. The analysis applied social cognitive theory, focusing on how individuals acquire and maintain behaviour. Also, expectancy theory was introduced, which posited that engineers are motivated to carry out professional activities based on the expected project outcomes. Besides, it emphasises the cognitive processes that engineers go through to make decisions about their actions in the professional environment during emergencies. Both theories enabled the conduct of structured opinion-based questionnaires on Likert scales and assessed engineering project success after introducing AI tools.

The research involved 96 participants who were engineers with diverse roles and expertise to provide a comprehensive view of the impact and effectiveness of AI tools in engineering project management during emergencies. They were systems engineers (3.1 %), data engineers (4.2 %), mechanical engineers (15.6 %), civil engineers (11.5 %), electrical engineers (14.6 %), industrial engineers (7.3 %), military engineers (13.5 %), research engineers (12.5 %), and engineering educators (17.7 %) who provide realisation of educational program "Organisation of activities of engineering and technical units of the State Border Guard Service of Ukraine". When including a range of engineering disciplines and roles, the survey gathered a well-rounded understanding of AI tools' impact on engineering project success during emergencies.

The study was organised between December 2023 and April 2024 in three Ukrainian regions – Khmelnytskyi, Odesa, and Chernivtsi. 53.1 % of participants represented civil companies that deal with car repairs and maintenance, as well as the construction and manufacturing of electrical machinery. 46.9 % of engineers were involved in military organisations and managed military engineering projects such as vehicle recovery system development and the establishment of equipped mobile maintenance units. Also, they participated in training future military engineers or conducted research in the field of special vehicle maintenance. All participants were informed about the research and participated voluntarily. The investigation was conducted on the principles of respect and confidentiality; the outcomes were assessed objectively to ensure accuracy and reliability.

A number of instruments were applied to answer the research questions. Firstly, structured opinion-based questionnaires on Likert scales to analyse (1) the challenges facing engineering project management during emergencies, by the example of Ukraine; (2) the efficient type of engineering project management during emergencies; (3) the skills which are necessary for 'engineers' AI readiness; and (4) the teaching strategies introduced within the system of continuous training of engineers to form AI readiness. The development of questionaries required clear articulation of the objectives; creation of close-ended specific questions; and the use of a balanced 5-point Likert scale. The researchers conducted a pilot survey among 12 participants to identify any issues with question clarity or scale interpretation. Secondly, the assessment of project success was based on critical success factors (CSFs) and involved a systematic procedure to ensure that essential project criteria were met under high-pressure conditions. A targeted methodology was employed to prioritise factors directly related to the challenges caused by the ongoing war and instability when we focused on identifying CSFs for engineering project management during emergencies in Ukraine. Prioritisation was driven by input from the participants, ensuring that the data reflected real-life conditions and the need for rapid decision-making in emergency scenarios.

Initially, CSFs relevant to the emergency context in Ukraine were identified and defined. They included the following: effective risk management (CSF_1), clear communication (CSF_2), adaptability (CSF_3), flexibility (CSF_4), skilled and experienced teams (CSF_5), detailed planning (CSF_6), resources management (CSF_7), quality control (CSF_8), 'stakeholders' satisfaction (CSF_9), and costs (CSF_{10}). Also, 5 CSFs related to AI applications were considered, such as data-driven decision-making (CSF_{11}), algorithmic optimisation (CSF_{12}), predictive modelling (CSF_{13}), automation and intelligent systems (CSF_{14}), and implementation of AI tools to assess project risks (CSF_{15}). After selecting 15 CSFs, the Generalised Success Index (GSI) was calculated. Since these CSFs are measured on different scales, we normalised them to a common scale, typically 0 to 1. This converts the CSFs into comparable units. The normalisation was executed using the following formula for each CSF:

$$\text{Normalized CSF} = \frac{\text{Actual Value} - \text{Min Value}}{\text{Max Value} - \text{Min Value}} \qquad (1)$$

Further, we calculated the Weighted score for each CSF. It is a composite metric which integrates key performance indicators (KPIs), such as project timeliness, cost, resource usage, adjustment to emergency, and risk management. Each of these KPIs is assigned a specific weight based on its relative importance in emergencies. The Weighted CFSs provide comprehensive and adaptable measures of success and help engineering project managers make accurate decisions and optimise project performance during emergencies. Each weighted CFS was determined according to the equation below:

$$\text{Weighted CSF} = \text{Normalized CSF} \times \text{Weight} \qquad (2)$$

All the weighted CSFs were used to get the GSI:

$$GSI = \Sigma(\text{Weighted CSFs}) \quad (3)$$

The GSI ranged from 0 to 1, where 0.9-1 indicated the engineering project was implemented successfully during an emergency. When the GSI was between 0.845 and 0.899, the project performed well under emergency conditions and achieved the project objectives. The value of GSI of 0.7-0.844 suggested that the project was completed, but it showed lower outcomes than expected. When the GSI was 0.699 or less, it was clear that engineers executed an engineering project in particular or did not complete it due to an emergency.

The data was analysed using statistical methods to identify patterns and accurate correlations. In this research, descriptive statistics was applied to interpret the data related to CSFs in engineering project management during emergencies, as they offer a clear summary of performance metrics. This method presented the average performance, main tendencies, and variability of critical factors. This analysis identified the advantages of AI tools when managing engineering projects across different emergencies. Besides, descriptive statistics were introduced to investigate the strengths of teaching strategies used to form AI readiness among engineers. The frequency analysis was used to describe the challenges of engineering project management and define AI tools used to enhance performance during emergencies. It examined the input data frequency and outlined the common 'participants' perceptions. The method provided the researchers with a quantitative basis for decision-making as well.

4 RESULTS

The findings demonstrated that engineering project management is facing ten main groups of challenges in Ukraine during emergencies ($C_1 \ldots C_{10}$). Table 1 shows that the challenges for engineering companies and military engineering units are caused by the Ukraine war and relate to disruption of supply chains, safety and security risks, workforce instability, communication barriers, poor resource allocation, and logistical, financial, and technological difficulties. Some challenges concern the introduction of martial law in Ukraine, which has resulted in regulation changes. The analysis revealed that C_1, C_2, and C_5 are the most frequent challenges.

Table 1 – Challenges engineering projects face during emergencies

Code	Challenges		Frequency
C_1	Disruption of supply chains	Difficulty in sourcing spare parts and materials	Frequently
		Limited availability of military-grade components	Frequently
C_2	Safety and security risks	Constant threat to personnel and infrastructure	Frequently
		High-risk environments	Frequently
C_3	Workforce instability	Workers may be displaced, injured, or enlisted	Sometimes

Code	Challenges		Frequency
C_4	Communication barriers	Interruption of communication networks	Sometimes
		Necessity for secure communication channels	Always
C_5	Resource allocation	Difficulty in prioritising resources	Frequently
		Need to balance resources between immediate military needs and longer-term engineering projects	Frequently
C_6	Logistical difficulties	Damaged infrastructure	Sometimes
C_7	Martial Law introduction	Adhering to strict military standards and protocols	Always
C_8	Financial challenges	Increased costs	Rarely
		Budget limitations	Rarely
C_9	Technological challenges	Unreliable internet and power	Rarely
C_{10}	Psychological impact	High stress among engineers	Sometimes

(Source: 'authors' calculations based on perception-based analysis)

At the same time, participants described three types of management in the Ukrainian context – traditional, agile, and hybrid (Figure 1). According to their perceptions, the traditional model is less efficient since it lacks flexibility, slow decision-making, limited 'stakeholders' engagement, and poor technology integration. Only 14.5 % of respondents stated that the traditional model is efficient and can be applied to manage engineering projects during emergencies. 25.4 % of participants agreed that the agile model contributes significantly to project success. Special attention was paid to the potential of the agile model to implement innovative technologies to enhance the productivity of an organisation during emergencies. 24.3 % of participants mentioned that the hybrid model is efficient, and a number of military engineering units actively incorporate hybrid types of engineering project management because it provides a flexible and adaptive model suitable for the complex and dynamic nature of military operations.

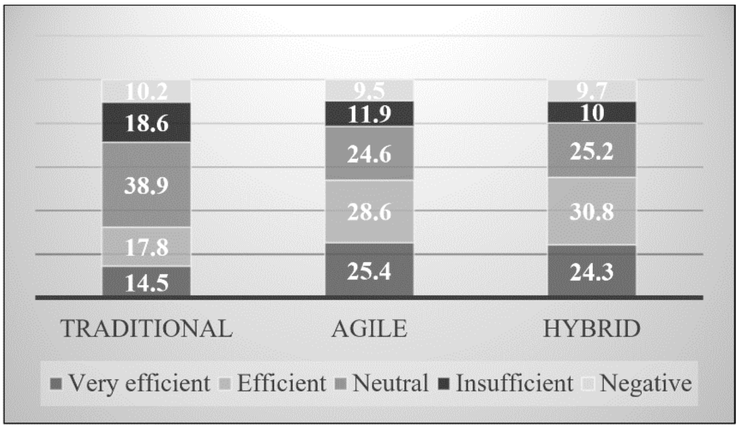

Figure 1 – Efficiency of types of engineering project management
(Source: 'authors' calculations based on perception-based analysis)

Table 2 presents 25 AI tools used to overcome the challenges ($C_1 \ldots C_{10}$) in engineering project management during emergencies. The 'participants' responses demonstrated that wearable technologies, AI-based analysis of incident reports, automated recruitment, machine translation, speech recognition and voice assistants, risk prediction and assessment tools, and AI-powered chatbots to provide mental health support caused the largest success of engineering projects during emergencies. At the same time, the GSI showed that some tools, such as automated warehousing, AI algorithms for transportation route optimisation, and virtual assistants, are effective under normal circumstances but do not significantly contribute to the success of large engineering projects during emergencies. This was due to the fact that they often rely on pre-programmed routines and fixed processes that do not quickly adjust to rapidly changing conditions. Also, some automated systems appeared vulnerable to technical failures and cybersecurity threats, leading to delays and inefficiencies in engineering project management during emergencies.

Table 2 – AI tools used to manage engineering projects during emergencies

Code	**AI tools**	**GSI**		
		Before AI	**After AI**	**Change**
C_1	Predictive analytics	0.765	0.823	+0.058
	Automated warehousing	0.811	0.809	-0.002
C_2	Wearable technologies	0.543	0.903	+0.360
	AI-driven cameras and image recognition software	0.830	0.915	+0.085
	AI-based analysis of incident reports	0.729	0.976	+0.247
C_3	AI-driven scheduling tools	0.769	0.814	+0.045
	AI-based skill gap analysis	0.648	0.716	+0.068
	Automated recruitment	0.548	0.753	+0.205
	Personalised learning platforms	0.837	0.985	+0.148
C_4	Machine translation	0.806	0.942	+0.136
	Speech recognition and voice assistants	0.455	0.578	+0.123
	AI-powered chatbots and virtual assistants	0.813	0.945	+0.132
	Collaboration platforms	0.845	0.979	+0.134
C_5	Budget management tools	0.751	0.803	+0.052
	Real-time reports on resource utilisation	0.677	0.807	+0.130
C_6	AI algorithms to optimise transportation routes	0.809	0.823	+0.014
	AI-enhanced warehouse management systems	0.814	0.889	+0.075
C_7	Risk prediction and assessment tools	0.403	0.801	+0.398
	Scenario simulation	0.799	0.854	+0.055
C_8	Automated bookkeeping	0.804	0.906	+0.102
	Procurement management tools	0.765	0.838	+0.073
C_9	Virtual assistants	0.751	0.743	-0.008
	Big Data analytics	0.648	0.712	+0.064
C_{10}	AI-powered chatbots to provide mental health support	0.453	0.675	+0.222

Code	AI tools	GSI		
		Before AI	After AI	Change
	AI-enhanced feedback systems	0.762	0.847	+0.085

(Source: 'authors' calculations based on perception-based analysis)

AI readiness among engineers was defined as a set of skills ($S_1 \ldots S_{12}$) to understand, implement, and use AI tools in engineering project management. The research outlined a number of skills comprising AI readiness (Table 3). We found that engineers considered S2, S6, S7, and S8. Participants admitted that the specialists equipped with skills can manage engineering projects successfully and apply AI tools for enhancement during emergencies.

Table 3 – Skills comprising AI readiness among engineers

Code	Skills	Very important	Important	Neutral	Not important	Negative
S_1	Tool-specific knowledge	24.5 %	37.8 %	21.4 %	10.1 %	6.2 %
S_2	Technical proficiency	32.7 %	43.6 %	12.5 %	8.8 %	2.4 %
S_3	Problem-solving	21.6 %	33.9 %	28.7 %	11.5 %	4.3 %
S_4	Critical thinking	28.3 %	35.1 %	21.6 %	9.6 %	5.4 %
S_5	Decision-making	23.9 %	41.4 %	20.8 %	13.2 %	0.7 %
S_6	Crisis response	37.1 %	38.5 %	22.9 %	1.5 %	0.0 %
S_7	Communication skills	26.4 %	31.5 %	23.0 %	15.3 %	3.8 %
S_8	Team collaboration	27.8 %	37.4 %	21.5 %	12.4 %	0.9 %
S_9	Adaptability and flexibility	21.9 %	41.6 %	19.7 %	13.7 %	3.1 %
S_{10}	Conflict resolution	19.3 %	46.2 %	23.8 %	9.2 %	1.5 %
S_{11}	Leadership	22.4 %	38.5 %	20.8 %	17.1 %	1.2 %
S_{12}	Ethics	18.9 %	29.7 %	38.5 %	10.2 %	2.7 %

(Source: 'authors' calculations based on perception-based analysis)

Continuous education is important for engineers during emergencies, such as the ongoing war in Ukraine, and it equips them with up-to-date skills necessary to adapt to rapidly changing conditions and implement innovative solutions effectively. AI readiness is mainly formed on-site because many engineering programs do not provide comprehensive training in AI due to the rapid pace of technological advancement. As a result, engineers often lack practical experience with AI tools and methodologies. Because AI tools have contributed significantly to the enhancement of engineering project management, the problem of the formation of AI readiness among engineers is worth explaining. It was found that to form AI readiness among engineers in the system of continuous education, certain teaching strategies ($T_1 \ldots T_7$) were used based on the authors calculation (Table 4).

The findings demonstrated that the system of continuous education of engineers with the use of the above-mentioned teaching strategies always or frequently leads to the creation of realistic professional experience (T_1), safe and adaptive learning environment (T_1), modelling of real-life scenarios (T_2), assumption of various roles within a team (T_2), increased confidence of engineers to act in the high-pressure environment (T_2), and development of practical skills (T_3). Also, these teaching strategies foster collaboration and communication (T_3), address various emergency scenarios (T_3) as well as provide convenient access and flexible scheduling (T_4), on-to-one attention (T_5). In addition, they create the opportunity to use diverse perspectives, leading to more innovative solutions in engineering project management during emergencies (T_7).

Table 4 – Teaching strategies to form AI readiness among engineers

Code	Teaching strategy	Strengths	Frequency
T_1	Simulation-based learning	Realistic professional experience	Always
		Safe and adaptive learning environment	Frequently
		Engagement and increased motivation	Sometimes
T_2	Role-playing	Modelling of real-life scenarios	Frequently
		Assumption of various roles within a team	Always
		Increased confidence	Frequently
T_3	Interactive workshops	Development of practical skills	Frequently
		Fostering collaboration and communication	Frequently
		Address specific learning objectives and emergency scenarios	Frequently
		Modifications based on feedback and learning outcomes	Sometimes
T_4	Online courses	Convenient access and flexible scheduling	Frequently
		Automated quizzes and assessments for immediate feedback	Sometimes
T_5	Mentoring	One-on-one attention	Frequently
T_6	Peer learning	Mutual support and encouragement	Sometimes
		Improvement of communication skills	Sometimes
T_7	Collaborative projects	Enhanced learning experience	Sometimes
		Use of diverse perspectives leading to more innovative solutions	Always

(Source: 'authors' calculations based on perception-based analysis)

4 DISCUSSION AND CONCLUSION

The literature review demonstrated that engineering project management faces many challenges during emergencies and requires special attention among scholars and practitioners. The comprehensive research conducted in Khmelnytskyi, Odesa, and Chernivtsi regions in Ukraine among 96 participants representing civil engineering companies and military engineering units proved that some challenges emerge and hinder engineering project management. It was found that disruption of supply chains, safety and security risks, and poor resource allocation are frequent challenges of engineering project management in the Ukrainian context. Other difficulties include workforce instability because workers can be displaced, injured or enlisted in military service, communication barriers, negative psychological impact, and logistical, financial, and technological challenges. Besides, martial law introduces strict military standards and protocols to engineering project management.

The recent findings showed that three types of engineering project management are used during emergencies. They include traditional, agile, and hybrid. Ukrainian engineering companies and military engineering units apply the same management models to achieve project outcomes during emergencies. According to perception-based analysis, agile management is the most efficient, and it brings enhanced flexibility, improved collaboration, and better risk management. At the same time, the agile model contributes to implementing innovative technologies in engineering project management, particularly because it incorporates AI tools. A hybrid type of engineering project management is applied widely in military engineering units since they perform their activities within a structured command system, on the one hand, and use innovations to counteract emerging threats, on the other hand.

The scientific works on the topic revealed that AI-based tools contribute to data-driven decisions, automated routine tasks, and continuous monitoring of project progress. AI also assists in quality control, adaptive scheduling, risk management, improved safety, and proactive planning. To overcome the emerging challenges, a number of AI tools are used in engineering project management. According to the survey participants, some of them include: predictive analytics, automated warehousing, wearable technologies, image recognition software, scheduling tools, virtual assistants, collaboration platforms, risk prediction and assessment tools, scenario simulation, and feedback systems. On the basis of GSI calculations, it was stated that AI tools enhance engineering project management during emergencies. In high-pressure situations, such as full-fledged war, AI can analyse large amounts of data to predict potential risks, optimise resource deployment, and identify the most effective interventions. AI-driven simulations help engineers prepare for various emergency scenarios and respond to them promptly.

CSFs include skilled and experienced teams reflecting the necessity of professional training of engineers oriented towards their preparation to provide innovative solutions in engineering project management during emergencies. AI readiness involves training engineers to apply AI tools in practical scenarios, including their ability to adapt to existing challenges. The perception-based analysis demonstrated that AI readiness comprises tool-specific knowledge, technical proficiency, problem-solving, critical thinking, decision-making, crisis response, communication and collaboration skills, adaptability, conflict resolution, leadership, and ethics. Combined, they enable engineers to manage projects during emergencies. AI readiness is continually developing and requires ongoing improvement due to the rapidly evolving nature of AI. Engineers must update their skills as AI tools advance to stay aware of the latest innovations. According to the outcomes, simulation-based learning, role-playing, interactive workshops, online courses, mentoring, peer learning, and collaborative projects are implemented within the continuous education system, resulting in high levels of AI readiness among engineers.

The investigation makes it evident that engineering project management needs improving through the implementation of AI tools and the organisation of advanced training of engineering project managers during emergencies. The Ukrainian experiences show that engineering project management is uniquely shaped by the ongoing war, which imposes significant challenges on infrastructure development and project execution. In this environment, the integration of AI tools becomes significant for managing projects, both civil and military, effectively. The findings can be used to improve training programs for engineers since integrating AI-focused modules emphasises practical experience with AI technologies and prepares specialists to improve project outcomes, reduce risks, and enhance the organisation's productivity during emergencies.

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CONFLICTS OF INTEREST

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