ASEAN Engineering Journal

Full Paper

CHALLENGES AND BARRIERS FOR UNMANNED AERIAL VEHICLE (UAV) IMPLEMENTATION IN MALAYSIAN INFRASTRUCTURE PROJECTS

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Article history
Received
14 June 2023
Received in revised form
10 September 2023
Accepted
21 September 2023
Published online
29 February 2024

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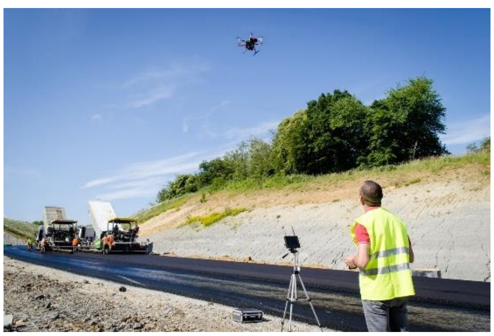

Abstract

The usage of Unmanned Aerial Vehicles (UAV) in infrastructure projects has inclined drastic recently due to its benefits. However, there is a slowness in transition from conventional construction approach to new innovation. Besides, there are lots of issues in current practices such as cost overrun, dangerous, delay of time completion and lack of an overall comprehensive scientific system. Furthermore, although there was high level of awareness on the advantages of using UAVs, the Malaysian construction industry are still reluctant for the changes. In response, to overcome issues that the construction industry faces, such as infrastructure projects thus, this study aims to develop a conceptual framework for promoting the applications of UAV in Malaysia infrastructure projects. The methods adopted in this researchinclude explanatory sequential research methods. For instance, questionnaire surveys and interviews are used to collect quantitative and qualitative data, respectively. As a result, the current application of UAV in Malaysian infrastructure projects in term of monitoring and inspection have similar challenges and barriers to those identified by previous researchers, but there are also some new challenges that have arisen, such as the need for education among contractors and guidelines on autonomous UAV. Besides that, a refined conceptual framework of the challenges and barriers of UAV adoption in Malaysia infrastructure projects were mainly contributed by the restrictive regulatory environment and industry point of view. For example, the privacy issues and guidelines on autonomous UAV and the industry lack of confidence in the adoption of UAV and education on the adoption of the UAV. In addition, it offers some solutions for the issues that have been revealed in the preliminary conceptual framework for the challenges on UAV adoption in Malaysia infrastructure projects. For instance, amaze the contractor with the final data from the UAV. Lastly, the identify solution served as a reference for other Malaysian construction stakeholders that have not used UAVs before. The recommendations for future scholarly research include the roles of UAV technology with other technologies such as Artificial Intelligent (AI) or integration of data with other software.

Keywords: unmanned aerial vehicle, Infrastructure, challenges, Nvivo, content analysis

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1.0 INTRODUCTION

The COVID-19 outbreak, which began in December 2019, has severely impacted the economies of many countries, including Malaysia. According to Xiaolong et al. (2021) [1], infrastructure development has played a critical role in reviving these economies. Malaysia has made significant progress in completing several infrastructure projects, such as the Mass Rapid Transit (MRT) 2 and the Sungai Besi–Ulu Klang Elevated Expressway (SUKE), as of 30th June 2022. Despite being a developing country, the Malaysian government has announced that it will continue to undertake new infrastructure projects, such as MRT 3, the Petaling Jaya Dispersal Link (PJD Link) expressway, the Bangi-Putrajaya Expressway (BPE), and the Kuala Lumpur Northern Dispersal Expressway (KL NODE), in the Klang Valley region. As a result, Malaysia's infrastructure volume is expected to gradually increase in 2022 and beyond. It is important for the government to invest in infrastructure projects that will support Malaysia's future growth and development. To ensure sustainable growth for the country, it is essential to focus on key types of infrastructure projects such as bridge infrastructure, communications infrastructure, power and energy infrastructure, railroad infrastructure, road infrastructure and water infrastructure.

Zafrul (2021) [2] has highlighted that the Malaysian government is seeking a better technological approach to support mega infrastructure projects like the East Coast Rail Line (ECRL), MRT 2, and Light Rail Transit (LRT) 3, with the aim of boosting the country's economic growth. Recent infrastructure projects, including the SUKE, ECRL, and the Pan Borneo Highway have already contributed to better connectivity and reduced traffic congestion [3-6]. As a result, both the government and industry players are working towards transforming the construction sector to Industry Revolution (IR) 4.0, which is characterised by digitisation and smart production [7]. Moreover, Lau et al. (2021) [8] have suggested that Malaysia's construction industry needs to embrace digitalisation to keep up with the changing market. They argue that organisations or industries that lack a focus on digitalisation will be left behind. During the Virtual World UAV Summit 2021, Speaker Farhan, the head of drone tech ecosystem sandbox, has also noted that Malaysia's drone tech industry has the potential to contribute to the country's economic growth, create job opportunities, and increase digital adoption [9]. Thus, it is vital for Malaysia's construction industry to shift towards digitalisation to stay competitive and advance its economic growth. Besides, Sr Saiful Aziz, assistant director of survey from the Department of Survey and Mapping Malaysia (JUPEM), announced the establishment of a one-stop centre for shaping the future of drone operations in Malaysia. This centre will have three main objectives: centralising permit applications, registration and governance, and stakeholder monitoring compliance [10].

Studies by Seo et al. (2018) [11] have shown that UAV-enabled inspection methods are capable of identifying various forms of damage to specific timber bridges more efficiently than conventional inspection methods. However, Zakaria and Singh (2021) [12] discovered that COVID-19 has led to pandemic-related issues within Malaysia's construction industry, such as time delays, lack of manpower, postponement of contracts, and financial impacts. In response, some projects have been suspended, delayed, or altered, and management has attempted to adopt technology to perform tasks remotely when possible [13]. Xu and Turkan (2019) [14] also found that current methods for checking bridge inspection practices are inefficient due to their time-consuming, costly, dangerous, and subjective nature. Furthermore, traditional measurement techniques for detecting flaws in the bottom of bridges and power station surveys rely heavily on the experience of managers and technicians, which lack an overall, comprehensive, and scientific system method, resulting in delayed feedback to managers [15].

Since 2018, the Malaysian government has been promoting digitisation through the adoption of Building Information Modelling (BIM), UAVs, and other IR) 4.0 technologies. These efforts aim to acquire the necessary data for quick problem resolution and to create a cooperative business environment in project design schemes, building and operation, deployment of resources, and safety and quality improvements [16]. The use of UAVs or drones has been identified as an effective tool for monitoring infrastructure, evaluating the entire structural construction area, and taking specific photographs for each work activity [17]. However, the research is limited to a single application case, which affects the generalisability of its conclusions [17]. Despite the potential benefits of UAV technology, the Malaysian construction industry has been slow to adopt innovative practices due to a conservative approach [18]. Future studies are needed to explore the advantages and limitations of UAV technology in various construction processes [19]. The use of Internet of Things (IoT) and UAVs has been found to help meet client standards, expectations, and the most critical success factor of quality management in building projects [20]. However, UAV technology is still in its infancy and has yet to make a significant impact on the Malaysian construction industry [21]. The journal suggests that training, education, and roadshows are needed to encourage the application of drone technology within the industry and address the challenges hindering its adoption. The research discussed does not pertain to a specific project and is based on a regulatory or safety perspective. Similarly, Chand et al. (2021) [22] identified the advantages, and challenges of UAVs in the construction industry by reviewing literature from 2012 to 2021, but the study did not propose any solutions for the identified challenges nor did it address the limitations of the construction industry. As Elghaish et al. (2020) [23] highlighted, the digital transformation of construction necessitates utilizing a wide range of technologies. Consequently, there has been significant progress in exploring the adoption of technologies such as UAVs as immersive technologies in construction over the past two decades. The author notes that the focus of UAV-based applications thus far has been on popular themes such as automated surveying, information management, visualization, and safety management employed in construction, inspection, and monitoring. However, Elghaish et al (2020) [23] suggest that future studies should delve deeper into the usage of UAVs in construction-site management, the feasibility of their application in construction projects, and the extent of disruption to current practices caused by the introduction of UAVs, along with the associated costs.

The Malaysian government has been promoting the use of IR 4.0 technology and advocating for digitalization. However, according to Fui (2020) [24], the construction industry faces challenges in adopting IR 4.0 due to a lack of awareness, especially regarding construction 4.0 technology, and the absence of comprehensive policies and incentives. Additionally, Aripin et al. (2019) [25] investigated the factors that influence the implementation of IR 4.0 technologies in the Malaysian construction industry, such as a lack of knowledge, individual hesitance and etc. Despite a high level of awareness of UAVs, there is a low level of usage in construction, as reported by Charlesraj and Rakshith (2020) [26]. Nevertheless, according to Albeaino et al. (2022) [27], challenges related to drone technologies, pilot training, weather and job site conditions, and flight regulations remain a hurdle to UAV adoption in the construction industry. Thus, they recommend further research to understand and mitigate these challenges. Therefore, this paper aims to quantitatively prioritize the challenges and barriers associated with UAV adoption in Malaysian infrastructure projects.

2.0 METHODOLOGY

In this research, a pre-test was conducted to validate the questionnaire survey. The pre-test questionnaire was reviewed by industry and academic experts before the final version was distributed to the respondents. The pre-test revealed some issues, such as the need for a brief explanation of UAVs in the cover letter and the necessity to change the question in Section 1 from "what describes your firm" to "what is the nature of your company" to better distinguish between subcontractors and main contractors, as well as developers or Quantity Surveying (QS) firms. Additionally, when using abbreviations, the full term should be included to ensure all participants understand them. For example, CAAM should be defined as Civil Aviation Authority of Malaysia. Furthermore, the interview questionnaire was pre-tested with industry and academic experts to ensure that the questions aligned with the research questions. During the pre-test, the experts suggested reordering and reframing some of the questions and correcting any grammatical errors to prevent confusion.

The survey questionnaire used in this research consisted of close-ended questions organised into three sections. Section A gathered participant profiles, Section B collected respondents' views on the challenges associated with UAV application in Malaysian infrastructure projects and Section C gathered respondents' views on the barriers associated with UAV application in Malaysian infrastructure projects. The responses helped to achieve Objective 2 of this research, which is to quantitatively prioritise the challenges and barriers associated with UAV application in Malaysian infrastructure projects. A six-point scale with a forced choice was used to provide better data and to allow for a neutral option, the slightly agree and slightly disagree responses can be averaged together [28]. An even number of items in the response scale can yield groupings that are easier to understand and discuss. This means groupings of unfavorable, uncertain and favorable in many organisations [28]. Therefore, the questionnaire in this research adopted a six-point Likert scale as it would enable easy grouping and discussion. Additionally, Allen (2017) [29] revealed that offering an incentive is essential since research results show that it typically lifts response rates by 10-15%. Therefore, a small incentive, a draw of two RM 100 prizes, was offered to participants willing to enter a prize draw as a gesture of appreciation in the questionnaire survey.

2.1 Population and Sampling

This research uses a non-random sampling technique to gather data from site engineers, construction managers, project managers and site supervisors. The questionnaire was distributed to all parties involved in an infrastructure construction project, ranging from site supervisors to managerial levels, such as QAQC engineers, construction managers and project managers. A potential sample of Grade 6 to 7 contractors is included because they typically have a large paid-up capital and greater capacity to tender for complex and costly infrastructure projects. To determine the sample size, a G power analysis programme 3.1.9.7 was used, with a required significance level of 0.05 for regression analysis, a large effect size of 0.72 according to Cohen's Law, a power of 0.95 and two predictors, namely the challenges and barriers associated with UAV application in Malaysian infrastructure projects [30-31].

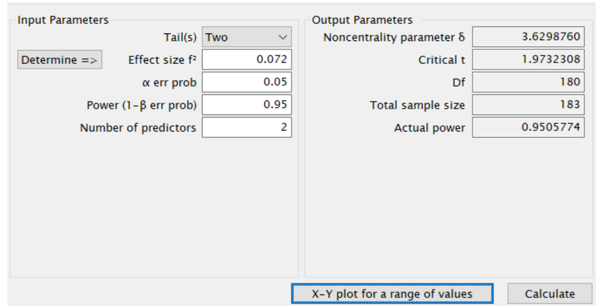

Figure 1 Sample size based on G power analysis

The required sample size for the questionnaire survey in this research is 183, as shown in Figure 1. However, due to time and cost constraints, the distribution of the questionnaire survey to relevant participants was done online through email and social media platforms, with a total of 1185 questionnaires sent out. According to research by Menon and Muraleedharan (2020) [32], the median survey response rate for an online survey is 26.45%, with a range between 25% to 30%. Despite sending out more than the suggested number of questionnaires to achieve the required sample size, only 120 responses were collected due to the lockdown period.

The questionnaire survey is aimed at stakeholders involved in infrastructure construction projects in Malaysia, from site supervisors to managerial level staff, such as QAQC engineers, construction managers, and project managers. The collected questionnaire data was analysed using IBM SPSS software.

3.0 RESULTS AND DISCUSSION

A reliability and stability test were performed on Sections B and C of the questionnaire survey following the method described by Meng et al. (2019) [33]. The authors suggest that a Cronbach's alpha value of at least 0.7 is acceptable, while a higher value is preferable. Table 1 has summarized the respondents profile that consist of all parties involved in an infrastructure construction project, ranging from site supervisors to managerial levels.

To analyse the data from Section B, the Relative Importance Index (RII) was used as recommended by Charlesraj and Rakshith (2020) [26]. The RII allows for the ranking of the indicators and determines their relative importance. The RII formula used in this research was

$$(6n_6 + 5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1)/(A * N)$$

where,
$6n_6$ =Number of respondents extremely disagree
$5n_5$ =Number of respondents very disagree
$4n_4$= Number of respondents somewhat disagree
$3n_3$= Number of respondents somewhat agree
$2n_2$= Number of respondents very agree
$1n_1$= Number of respondents extremely agree
A (Highest Weight) =6
N (Total number of respondents) =120
as suggested by Abdulrahim and Mabrouk (2020) and Oluwule (2011) [34,35].

Table 1 Respondents Profile

Profile category	Frequency (N120)	Percentage (%)
Current position		
Site supervisor	14.0	11.7
Site engineer/ project executive	51.0	42.5
Project manager	21.0	17.5
Director/ Founder	3.0	2.5
Other	31.0	25.8
Working experiences in the construction industry		
Less than 5 years	39.0	32.5
5 – 10 years	37.0	30.8
More than 10 years	44.0	36.7
Nature of the company		
Sub-contractor	36.0	30.0
Main contractor	84.0	70.0
Projects involved		
Highway	8.0	6.7
Mass transit	63.0	52.5
Waste management	3.0	2.5
Power and energy	9.0	7.5
Bridge	5.0	4.2
Water supply	1.0	0.8
Telecommunication	4.0	3.3
Highway, mass transit	27.0	22.5

Table 2 Top three rated challenges based on RII (overall)

Code	Variable	RII	Rank
Safety issues at the daily site operation			
A1	Unstable flying conditions may represent potential hazards to nearby workers	0.490	1
A2	Operator errors may represent potential hazards to nearby workers	0.446	2
A3	Faulty equipment may represent potential hazard to nearby workers	0.403	3
Local authority lack of promoting/ implementing new regulation on the use of UAV			
B1	Civil Aviation Authority of Malaysia (CAAM)	0.450	1
B2	Jabatan Kerja Raya Malaysia (JKR)	0.446	2
B3	Construction Industry Development Board (CIDB)	0.188	3
Economic Challenges			
C1	Low return on investment	0.525	1
C2	Capital intensive	0.449	2
C3	High initial capital investment	0.188	3
Effectiveness of UAV application			
D1	Inspection of defect work	0.481	1
D2	Safety Management		2
D3	Site Planning		3
Challenges during daily site operation			
E1	The adoption of UAV in infrastructure projects in Malaysia would require more people during the operation	0.619	1
E2	The use of UAV in the infrastructures project in Malaysia were unproved immature technology	0.596	2
E3	The use of UAV in the infrastructures project in Malaysia were unproved effective technology	0.590	3

The data analysis of Section B in the questionnaire survey revealed that challenges related to daily site operations were identified as the most significant for Malaysian infrastructure projects. These challenges primarily revolved around the need for additional personnel during UAV adoption for site operations and the perception that the use of UAVs in Malaysia is still in its early stages and lacks effectiveness [18,21]. One of the challenges highlighted is that the adoption of UAVs in construction sites requires additional personnel. This includes skilled operators who can effectively operate and maneuver the UAVs, as well as support staff who can assist in managing the UAV operations, data collection, and analysis. The need to allocate and train personnel specifically for UAV-related tasks adds an extra layer of complexity and resource allocation to daily site operations.

Addressing these challenges by ensuring adequate personnel with the necessary skills and fostering confidence in UAV technology can enhance the successful integration of UAVs, ultimately improving efficiency and data utilization in Malaysian infrastructure projects.

In addition to the challenges faced during daily site operations, Table 2 also identified the top three challenges across all categories. These include safety issues during site operations, the lack of promotion and implementation of new regulations by local authorities regarding UAV usage, and economic challenges. Furthermore, the effectiveness of UAV applications in defect work, safety management, and site planning was also highlighted as significant concerns.

In terms of safety issues during daily site operations, the top concern identified was the potential hazards to nearby workers resulting from unstable flying conditions (A1). This includes risks such as collisions, direct contact accidents, falling UAVs or payload due to technical malfunctions, and distractions that can compromise the safety and well-being of workers [36]. Safety officers can leverage these insights to enhance planning efforts and ensure the safe integration of UAVs in Malaysian infrastructure projects.

The most significant challenge highlighted within the economic challenges' category is the low return on investment (C1). This finding can provide valuable information for contractors, enabling them to make informed decisions when evaluating the potential adoption of UAVs in Malaysian infrastructure projects. By considering the financial implications and return on investment associated with UAV implementation, contractors can better assess the feasibility and potential benefits of integrating UAV technology into their projects.

Table 3 presents the barriers to the adoption of UAVs in Malaysia infrastructure projects, classified into technical difficulty, restrictive regulatory environment, and organisational barriers. The technical difficulties with the highest RII scores, as shown in Table 3, include vibrations of the mounted camera, low resolution of captured images, and poor quality of video processing (H1-H3). These issues can significantly impact the performance and reliability of UAVs during operations. For instance, vibrations of the mounted camera can lead to blurred or distorted images, making it difficult to obtain accurate data for analysis and decision-making [42]. This can hinder the effectiveness of UAV applications in tasks such as surveying, mapping, and inspections. Similarly, low resolution of captured images and poor video processing can compromise the quality and clarity of visual data collected by UAVs, limiting their usefulness in identifying critical details or detecting defects on construction sites.

Table 3 Top three rated barrier based on RII (overall)

Code	Variable	RII	Rank
Technical difficulties for adoption of UAV in Malaysia infrastructure project			
H1	Vibrations of the mounted camera	0.533	1
H2	Low resolution of the captured images	0.524	2
H3	Quality of video processing	0.519	3
Restrictive regulatory environment for Adoption of UAV in Malaysia Infrastructure project			
F1	Privacy issue	0.515	1
F2	Certification for pilot and flight	0.426	2
F3	Safety	0.418	3
Industry point of view for adoption of UAV in Malaysia Infrastructure project			
G1	Lack of confidence in the adoption of UAV	0.435	1
G2	Lack of government incentives	0.422	2
G3	Shortage of technical skills in the labour force	0.419	3

To address these technical difficulties, manufacturers should prioritize improvements in product quality and performance. Manufacturers can provide UAVs with better image quality, reduced vibrations, and improved data processing capabilities, thereby enhancing their effectiveness and reliability in infrastructure projects. According to Outay (2020)[37], UAVs have potential applications in highway infrastructure management, including tasks such as bridge inspection, monitoring, and pavement distress recognition. However, there are certain limitations associated with the use of UAVs for these tasks. Furthermore, manufacturers can collaborate with industry professionals, researchers, and end-users to gather feedback, understand specific application requirements, and tailor their product development efforts accordingly. This collaborative approach ensures that the technological advancements align with the practical needs and challenges faced in infrastructure projects, leading to more reliable and efficient UAV solutions. An instance of such limitations is related to technological constraints, particularly regarding the battery life of drones. Researchers have been working on improving drone battery life through various means, such as advancements in lithium-ion batteries and exploring alternative energy sources like solar energy (Menouar et al., 2017)[38].

The top-rated restrictive regulatory environment factors were identified as privacy issues, certification for the pilot, and flight and safety requirements (F1–F3). This highlights the need for local regulatory agencies to review and improve regulations to ensure the safe and effective use of UAVs in infrastructure projects. Authorities have expressed concerns regarding safety and privacy in relation to drone operations. To address these concerns, they have implemented various restrictions to regulate drone usage. These restrictions encompass factors such as drone weight, equipment like cameras or sensors, limitations on operating during daylight hours, altitude restrictions, mandatory professional training and certification for operators, drone registration, and obtaining prior permissions for accessing controlled airspace. These measures, as highlighted in the FAA News (2016)[39], are aimed at ensuring responsible drone operation and mitigating risks associated with safety and privacy. Moreover, the limited adoption of drones can also be attributed to the lack of government support in establishing a regulatory framework, which raises concerns regarding privacy and security [21].

The study highlighted industry-related barriers that hinder the adoption of UAVs in Malaysian infrastructure projects. One of the barriers is the lack of confidence among industry stakeholders in adopting UAVs (G1). For example, construction companies may be skeptical about the effectiveness and reliability of UAV technology in improving project outcomes.

Another industry-related barrier is the lack of government incentives to promote UAV adoption (G2). Without financial incentives or supportive policies, organizations may hesitate to invest in UAV technology. In addition, Umar (2021)[40] has also suggested that the adoption of drones in various industries, including construction, requires significant investment encompassing hardware, software, and system integration. However, some smaller contractor firms may hesitate to invest in such technology due to uncertain benefits. The economic conditions in a region can play a significant role in promoting the application of drones in the construction industry. As emphasized by Umar et al. (2020)[41], the economic conditions, including the number of contracts awarded during a specific period, can act as important barriers to drone implementation. Contractors may become more optimistic about adopting new technologies like drones, as they hope it can enhance construction progress.

The shortage of technical skills in the labour force (G3) is another significant barrier. Many construction companies may not have personnel with the necessary expertise to operate UAVs effectively and analyze the data collected. Regarding the operation of drones, there is a challenge in developing and acquiring new competencies to optimize project organization and attract skilled individuals to the workforce. One of the main criteria for attracting new talents is the availability of employees with shared technical knowledge and integration experience [25].

By addressing these industry-related barriers, local government agencies and drone operators can foster a conducive environment for the adoption of UAV applications in Malaysia's infrastructure projects. For instance, the government can collaborate with industry stakeholders to organize awareness campaigns and training initiatives that highlight the benefits of UAVs and provide resources for upskilling the workforce. This collaborative effort can create a positive momentum, leading to increased confidence, greater government support, and a skilled labor force, ultimately driving the wider adoption of UAV technology in the construction industry.

4.0 CONCLUSION & FURTHER RECOMMENDATION

Based on the results of this research, it is evident that there are some challenges and barriers that are similar to those identified by previous researchers, but there are also some new challenges that have arisen, such as the need for education among contractors and guidelines on autonomous UAV. It is important to note that previous research has focused on the challenges and barriers in the construction industry as a whole, without differentiating between infrastructure, residential, or commercial construction projects. Additionally, previous research has focused on well-developed countries such as the USA and Singapore, which have different policies, labour costs, and work practices than Malaysia.

To further improve the understanding of the challenges and barriers of UAV adoption in Malaysian infrastructure projects, future research can take a more comprehensive approach. For instance, researchers can conduct in-depth interviews or surveys with key stakeholders, including construction project managers, drone operators, regulatory agencies, and workers to gain a better understanding of their perspectives on UAV adoption. By doing so, researchers can identify the specific needs and requirements of each stakeholder group, and tailor solutions and best practices accordingly.

Additionally, future research can explore the potential benefits of UAV adoption in Malaysian infrastructure projects, beyond the challenges and barriers identified in this study. For example, researchers can investigate the impact of UAVs on project timelines, costs, and quality, as well as their potential to enhance safety and sustainability practices. Furthermore, future research can evaluate the effectiveness of existing regulations and guidelines related to UAV adoption in Malaysia. By identifying gaps and opportunities for improvement, researchers can provide recommendations to regulatory agencies and policymakers to promote the safe and efficient integration of UAVs in infrastructure projects.

In summary, there is still much to be learned about the challenges and opportunities of UAV adoption in Malaysian infrastructure projects. Future research can take a more comprehensive and interdisciplinary approach to address these issues and provide a solid foundation for the construction industry to adopt and benefit from this emerging technology.

Acknowledgement

This work was sponsored by the Universiti Teknologi Malaysia Encouragement Fundamental Research (UTMER) program [grant number Q.J130000.3822.31J98]. We also grateful for valuable comments and suggestions from reviewers that help to improve our paper quality.

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