



UTS
ePRESS

Construction
Economics and
Building

Vol. 22, No. 4

December 2022



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Citation: Tjandra, K. D., Irawan, F. G., Nugraha, P., Sunindijo, R. Y. 2022. Drone Readiness in the Indonesian Construction Industry. *Construction Economics and Building*, 22:4, 36–58. <https://doi.org/10.5130/AJCEB.v22i4.8161>

ISSN 2204-9029 | Published by UTS ePRESS | <https://epress.lib.uts.edu.au/journals/index.php/AJCEB>

RESEARCH ARTICLE

Drone Readiness in the Indonesian Construction Industry

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DOI: <https://doi.org/10.5130/AJCEB.v22i4.8161>

Article History: Received 14/04/2022; Revised 02/09/2022; Accepted 26/09/2022; Published 15/12/2022

Abstract

Despite being perceived as a traditional industry, the construction industry is slowly being ushered into the Construction 4.0 era. Drone technology is seen as a disruptive, game-changing technology that has the potential to improve performance across all construction phases. However, despite the size of the country and its rapidly growing construction industry, research on drone technology in the Indonesian construction industry is limited. This research, therefore, aims to assess the drone readiness of construction practitioners in Indonesia and use the findings to recommend ways to promote its use. Readiness in this research is reflected by levels of understanding, utilisation, and interest in drone technology, as well as barriers to using drones at work. Data collected using a questionnaire survey from Surabaya, the second largest city in the country, reveal that, despite the relatively high level of interest, levels of understanding and utilisation are low. Furthermore, the lack of skilled human resources, risks associated with using drones, high costs, and limited information about drone suppliers are barriers that hinder the adoption of this technology in the Indonesian construction industry. This study fills the gap in the current research on the use of drone technology in the construction industry and provides a basis for practitioners or researchers to promote the application of the technology.

DECLARATION OF CONFLICTING INTEREST The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. **FUNDING** The author(s) received no financial support for the research, authorship, and/or publication of this article.

Keywords

Barriers; Construction Industry; Drones; Indonesia; Interest; Readiness; Understanding; Utilisation

Introduction

It is widely known that the construction industry is a strong contributor to the economic development of nations. In developing countries, construction is a crucial industry because of its contribution to macroeconomic growth ([Anaman and Osei-Amponsah, 2007](#); [Kementrian Keuangan Republik Indonesia, 2018](#)) and the dependence of various industrial sectors on the products of the construction industry ([Budiwibowo, et al., 2009](#)). In recent years, with the development and improvement of digital technologies, the construction industry is overcoming its resistance to innovation and slowly entering the digital era, which is sometimes referred to as Construction 4.0 ([Li, Greenwood and Kassem, 2019](#); [Sawhney, Riley and Irizarry, 2020](#)). Adopting innovative technologies, such as digital twin, building information modelling, automation, prefabrication, and wearable technologies, is touted as a way to improve productivity and transform the industry into a collaborative, modern, efficient, and safe industry ([Manzzor, Othman and Pomares, 2021](#); [Wang, et al., 2020](#)).

Another technology that is gaining popularity in the construction industry is drone. Drones have digitally transformed the construction industry and have been adopted in several aspects, like architecture, construction engineering and operations, and facility management ([Adepoju, et al., 2022](#)). For instance, drones can be applied to survey lands and provide topographic maps in the pre-construction phase ([Bogue, 2018](#); [Siebert and Teizer, 2014](#)). In the construction phase, they can be used for a wide range of activities, such as inspecting buildings, observing equipment and materials, providing progress reports, and observing the performance of workers ([Hubbard, et al., 2015](#); [Ratajczak, Riedl and Matt, 2019](#); [Kim, et al., 2019](#)). In the operational phase of a facility, they are useful for conducting inspections in hard-reached areas for maintenance purposes ([Sampaio, Rosario and Gomes, 2012](#); [Ezequiel, et al., 2014](#)). Construction organisations also have used drones for marketing purposes, for instance, by providing walk-through updates on construction progress and showcasing the overall development to their clients. The integration of artificial intelligence (AI) and autonomous navigation into drones can further increase their functionality and value to improve the performance of the industry ([Tal and Altschuld, 2021](#)).

It is envisioned that drone technology will eventually penetrate the construction industries in developing countries, including Indonesia. As a large and rapidly developing country in Southeast Asia, the Indonesian construction industry has received strong support and attention from the government ([Telaga, 2018](#); [Lestari, et al., 2020](#)). It was estimated that the amount of construction investment in Indonesia would grow by 5.2% annually ([Global Business Guide, 2016](#)). Indonesia is also predicted to be the fifth-largest construction market in the world in 2030 and the fourth-largest contributor to global growth in construction output ([Robinson, Leonard and Whittington, 2021](#)). Despite the size of the country and the rapid growth of the industry, construction organisations in Indonesia are reportedly insensitive to changes in technology ([Soemardi, et al., 2021](#)). In recent years, although there has been more attention to Construction 4.0 in the Indonesian construction industry, research and its application are limited. Specifically, research on the use of drones is rare. Research in Indonesia has previously focused on the application of drones for land mapping ([Radjawali, Pye and Flitner, 2017](#)), flooding events and the effects of tides ([Hermawan, et al., 2019](#)), and health and safety inspection ([Mansur and Lestari, 2019](#)). These studies have undeniably contributed to the application of drone technology in the country, but there is still a lack of understanding of the use of drones in the construction industry.

The readiness of construction practitioners in Indonesia is a key driver of the use of drone technology and ushering the sector into the Construction 4.0 era ([Mansour, Aminuddin and Mansour, 2021](#)). However, research on this in the context of Indonesia is non-existent. Therefore, in order to fill in this significant

research gap, this research aims to assess the level of readiness, represented by understanding, utilisation, and interest, of Indonesian construction practitioners in using drones in their projects. Barriers that constrain the use of drones are also investigated. By understanding the level of readiness and barriers to the use of drone technology, interventions and efforts to promote its use in the Indonesian construction industry can be recommended.

Literature review

A drone, also called unmanned aerial vehicle (UAV), unmanned aerial system (UAS), or remotely piloted vehicle (RPV), is defined as a space-traversing vehicle that flies without a human crew on board and that can be remotely controlled or can fly autonomously ([Yanushevsky, 2011](#); [Siebert and Teizer, 2014](#)). Because of affordability, manoeuvrability, and safety, drones have more possibilities than traditional methods, e.g., satellites and manned vehicles, for fulfilling the increasing and diverse needs in many domains to provide a variety of productive solutions ([Siebert and Teizer, 2014](#); [Omar and Nehdi, 2017](#); [Khan, Gupta and Gupta, 2021](#)).

A drone can assist construction practitioners in all phases of construction, including the pre-construction phase, construction phase, post-construction phase, and the entire construction phase, as summarised in [Table 1](#). The 10 drone functions are described in the following sections.

Table 1. Drone functions in construction

Category	Function	1	2	3	4	5
Pre-Construction Phase	Land Surveys	v				
	Photogrammetry for Topographic Mapping	v				
Construction Phase	Equipment and Material Monitoring	v	v			v
	Building Inspection	v	v	v	v	
	Remote Monitoring and Progress Reporting	v	v	v	v	
	Worker Surveillance	v	v			v
Post-Construction Phase	Final Inspection of Completed Building		v	v	v	
	Building Maintenance using Thermal Sensors	v	v	v	v	
Entire Construction Phase	Promotional Videos	v	v		v	
	Security Monitoring	v			v	

Note: 1: [Tal and Altshuld \(2021\)](#); 2: [Tkac and Mesaros \(2019\)](#); 3: [Ciampa, De Vito and Pecce \(2019\)](#); 4: [Mahmood \(2021\)](#); 5: [Hardjo, Wahyuni and Rahim \(2020\)](#)

PRE-CONSTRUCTION PHASE

The first drone function in construction is for land surveying. Land surveying is a fundamental procedure for all types of land development projects. Compared to traditional land surveying, the application of drone technology reduces the reliance on bulky traditional equipment such as tripods and total stations, reduces cost, and increases the efficiency of the land surveying phase. [Siebert and Teizer \(2014\)](#) compared the use

of drones with a real-time kinematic Global Positioning System (GPS) survey and reported that the use of drones can shorten the time by one-third to complete the task volume done by the traditional method. Additionally, drone technology can increase point density by more than 3,000 times, thus providing richer and more accurate data. Drones provide a clear inspection of the entire site and surroundings before starting work on site. As a result, construction practitioners can use the information to make better design decisions, spot hidden objects, and identify potential problems during construction ([Tal and Altschuld, 2021](#)).

Photogrammetry for topographic mapping is the second drone function in this phase. Photogrammetry is a technique to make reliable measurements by using aerial photographs ([Tal and Altschuld, 2021](#)). It is intended to assemble a large picture by using smaller photo offsets. The more photo offsets are taken, the better the final quality of the picture is ([Sutanto and Ridwan, 2016](#)). This technique was previously done with an aeroplane, and typically only two-dimensional pictures were taken. Nowadays, a drone can collect data faster with much better resolution ([Tkac and Mesaros, 2019](#)). For using the photogrammetry technique, a drone should be equipped with LIDAR (light detection and ranging) or TLS (terrestrial laser and ranging) ([Ouédraogo, et al., 2014](#)). The output of data the drone can produce for photogrammetry is XYZ coordinates and RGB colour gradation ([Tal and Altschuld, 2021](#)). With this function, a drone can acquire accurate data for developing a topographic map efficiently. A topographic map is useful in the planning and design stage, especially when involving a large area, such as assisting architects in designing a new building on slopes and developing geometric designs of highways.

CONSTRUCTION PHASE

The third drone function, which is part of the construction phase, is equipment and material monitoring. For instance, a drone can be utilised to detect, identify and track the location of tagged materials and their quantities ([Hubbard, et al., 2015](#); [Tal and Altschuld, 2021](#)). A drone can also help people check equipment conditions, such as a tower crane, which usually is challenging to do manually ([Tkac and Mesaros, 2019](#)). Besides completing the work in a more efficient manner, this practice can improve health and safety on construction sites ([Hardjo, et al., 2020](#)).

Performing building or facility inspection is the fourth drone function. When inspecting a building manually, workers sometimes need scaffolding, a body harness, an elevation platform, or a special vehicle to help them complete the inspection. In contrast, by using a drone, the risks related to performing those activities can be eliminated ([Ciampa, De Vito and Pecce, 2019](#)). A drone can also help inspectors identify a range of technical problems in facilities, such as checking the geometric dimensions of structures, the configuration of bolts on steel girders, and the conditions of curtain walls ([Liu, Jenness Jr and Holley, 2016](#)). It also helps them inspect parts of the building that are difficult to access, such as the top of a skyscraper ([Tkac and Mesaros, 2019](#)). This function is valuable as it can reduce operational and safety costs as well as inspection time ([Ciampa, De Vito and Pecce, 2019](#)).

The fifth drone function is remote monitoring and progress reporting. A drone can take pictures or videos of a building for progress reporting and quality control purposes ([Mahmood, 2021](#)). Drone technology provides cost-effective solutions for on-site data collection, data processing, progress upkeeping, and progress visualisation ([Jacob-Loyola, et al., 2021](#)). In fact, applying drones to collect images is considered the primary technology for upgrading 3D BIM models to 4D BIM models ([Tkac and Mesaros, 2019](#), [Jacob-Loyola, et al., 2021](#)). Through such an integrated approach, the documentation can be reviewed and linked with schedule and cost monitoring activities ([Tal and Altschuld, 2021](#)). Accurate documentation of progress is also important for progress payment or contract administration purposes. Furthermore, drone technology provides the opportunity for managers to monitor construction activities in real-time without being physically on-site ([Ciampa, De Vito and Pecce, 2019](#)).

The sixth drone function considered in this research is worker surveillance. Drone technology can help managers monitor whether workers conduct construction activities safely. For example, a drone combined with vision algorithms could check the use of personal protective equipment (PPE) of workers and promptly notify managers of individuals who are not properly equipped with PPE ([Israr, et al., 2021](#)). It can also help managers monitor the site conditions and housekeeping, so that preventive and corrective actions can be taken as necessary. This drone surveillance approach has been used for health and safety assessments and making decisions to improve health and safety, such as by identifying the need to install additional vertical or horizontal safety nets in high-rise buildings and determining their corresponding costs ([Hardjo, et al., 2020](#)). A drone has also been used to evaluate, and recommend ways to improve, worker productivity by, for instance, improving site layout ([Ham, et al., 2016](#)).

POST-CONSTRUCTION PHASE

The seventh drone function is for conducting final inspections of completed facilities before being handed over to the client. Similar to the other functions discussed earlier, drones can help inspectors efficiently and safely inspect building parts that are difficult to reach and in high places ([Moore, et al., 2018](#); [Mahmood, 2021](#)). Drones can also be used for periodic inspections during the operation stage of the building. By doing so, maintenance activities, such as those regularly required on building facades and roofs, can be done easily and safely ([Ciampa, De Vito and Pecce, 2019](#); [Tkac and Mesaros, 2019](#)).

The eighth drone function is for building maintenance using thermal sensors. Drones equipped with thermal sensor technology can detect problems invisible to the human eye ([Tkac and Mesaros, 2019](#)). In this case, thermal sensors can provide thermal images with colour gradations, which can detect the presence of steel bars, concrete cracks, water leakage, and humidity differences ([Ciampa, De Vito and Pecce, 2019](#); [Santano and Esmaceli, 2014](#); [Li and Liu, 2019](#)). It can also be applied to measure the surface temperature of building materials ([Tal and Altschuld, 2021](#)) and the temperature around electrical installations ([Mahmood, 2021](#)). Based on the information drawn from these images, practitioners can take appropriate actions to rectify problems.

ENTIRE CONSTRUCTION PHASE

The ninth drone function is for making promotional videos. It is relatively common nowadays to use drones for promoting businesses, including those in the construction industry. High-quality photos and videos can be captured by drones within a short period of time and can be easily adjusted to the required scale and size ([Mahmood, 2021](#)). The photogrammetry result and the 3D building model can be processed into videos, which have been previously used in the tendering process, while construction images are useful to enrich the contractor's portfolio ([Tal and Altschuld, 2021](#)).

The tenth drone function is for security monitoring, where drones serve as security cameras during construction or the operational stage of the facility. The recorded data can be used to evaluate the effectiveness of the existing security system ([Tal and Altschuld, 2021](#); [Alsamarraie, et al., 2022](#)). By integrating a thermal sensor on the drone, monitoring can be done at night, for instance, to prevent illegal and harmful activities.

READINESS TO USE DRONES

The rollout of new technology in the industry often takes time to be adopted widely and reap its expected benefits ([Saghafian, Laumann and Skogstad, 2021](#)). A readiness assessment is a way to observe the current situation in which the industry is ready, willing or prepared to adopt the innovation and enjoy its benefits

([Dada, 2006](#); [Jaafar, et al., 2007](#)). Through assessing the readiness for adopting drones, the current drone technology adoption status in the industry will be known, which will provide an understanding of current barriers and key support to promote its wider adoption. There are three dimensions considered in this research: levels of understanding, utilisation, and interest.

First, having an adequate level of understanding is essential in the process of adopting drone technology in an organisation. A good understanding or knowledge base is highly correlated with cognitive factors that promote the adoption of new technologies ([Marikyan, et al., 2022](#)). The process begins with individual understanding, before developing into a collective understanding within the organisation ([Han, et al., 2020](#)). The level of understanding can be measured based on how well construction practitioners understand the various functions of drones and their applicability to their work. Second, there is a need to assess the level of utilisation, which can be measured based on the frequency of construction practitioners in using drone technology at work. The process of adopting new technology is considered a diffusion process, meaning it occurs continuously and relatively slowly. As such, the more frequently drones are used, the more diffused their application at work is, indicating a higher readiness for its adoption. Third, the level of interest understandably plays an important role in the adoption of drones. Personal interest correlates with an individual's willingness to adopt a technology, with high personal interest indicating that individuals are more likely to accept and use the technology ([Kowatsch and Maass, 2012](#)). The same is true for drone technology, where the industry's willingness to embrace the technology is influenced by its level of interest. Interest itself grows through the realisation that drones can improve the process of performing construction activities.

Besides these three aspects, barriers perceived by construction practitioners also affect their readiness to use drones. [Tornatzky and Fleischer \(1990\)](#) developed the Technology, Organisation, and Environment (TOE) framework, which has been widely used to assess the barriers to adopting new technology ([Saghafian, Laumann and Skogstad, 2021](#)). The technological context considers the utilisation level of current technology, the disruption level of the new technology, and the risks associated with that new technology. The organisational context concerns organisational structure, the size of the organisation, resource availability, and the learning curve of using the new technology. The environmental context considers industry demand, supporting infrastructure technology, government regulation, industry maturity, and the capacity of suppliers ([Baker, 2012](#)).

Methodology

Quantitative methodology is adopted in the research due to the need to quantitatively assess the overall level of readiness for using drone technology in the Indonesian construction industry. A questionnaire survey was used to collect data from different types of construction practitioners, including contractors, construction management consultants, design consultants, and clients, to capture their readiness within the context. The questionnaire has three sections. The first section captured the demographic profile of the respondents, including gender, level of education, age, types of construction practitioners, occupation, and years of work experience. The second section assessed the three dimensions (understanding, utilisation, and interest), which reflect the readiness of construction practitioners to use the 10 drone functions in different construction phases. The third section assesses the relevance of the 12 barriers proposed in the TOE framework. [Table 2](#) lists the items in sections two and three of the questionnaires. Items A1 to D2 represent the 10 drone functions, while items E1 to E12 represent the 12 barriers. Guided by the TOE framework described by [Baker \(2012\)](#), items E1 to E4 represent technological barriers, items E5 to E8 represent organisational barriers, and items E9 to E12 represent environmental barriers. The 5-point Likert scales used to assess these items are presented in [Table 3](#).

Table 2. Questionnaire items

Code	Item
A1	Land surveys
A2	Photogrammetry for topographic mapping
B1	Equipment and material monitoring
B2	Building inspection during construction
B3	Remote monitoring and progress reporting
B4	Worker surveillance
C1	Final inspection of the completed building
C2	Building maintenance using thermal sensors
D1	Promotional videos
D2	Security monitoring
E1	Current technology and construction methods are still relevant without using drones
E2	Drone technology is changing rapidly, so it is quite hard to follow
E3	Risks associated with using drones
E4	Drone technologies and features have not entered Indonesia
E5	It takes too much time to learn about drone technology
E6	Drone technology is not supported by the company's management
E7	Company size is too small to adopt drone technology
E8	Lack of skilled human resources
E9	Current supporting technologies are inadequate, such as the internet, computer, and IT system
E10	There are no government regulations on the use of drones in the construction industry
E11	Limited information on drone suppliers
E12	The costs are too high compared to the benefits

Table 3. Likert scales

Scale	1	2	3	4	5
Understanding	Never heard	Heard only	Understand a little	Understand adequately	Advanced understanding
Utilisation	Never	Seldom	Sometimes	Often	Always
Interest	Very low	Low	Moderate	High	Very high
Barrier	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Data were collected by distributing questionnaires to construction practitioners, including designers, contractors, construction management consultants, and clients, in Surabaya, Indonesia. Surabaya is located on the island of Java, the world's most populous island, where more than 50% of the Indonesian population lives. As the second largest city after the capital Jakarta, Surabaya metropolitan area is home to nearly 10 million people, and the growing population stimulates the growth of the construction sector ([Susanto and Njo, 2019](#)). In previous research, the study of the construction industry in Surabaya was considered valuable for understanding the overall construction industry practice in Indonesia ([Aulady, et al., 2021](#)). Purposive sampling was used in this research, and it was implemented by visiting large construction sites and contacting established construction organisations in Surabaya. In total, 26 construction organisations, including contractors, design and construction management consultants, and client organisations (developers), participated in the survey, resulting in 120 valid responses. There were 95 offline responses and 25 online responses with a combined response rate of 61.86%.

Analysis and discussion

[Table 4](#) presents the demographic profile of the respondents. The majority of the respondents are male, reflecting the male-dominated characteristic of the industry. Nearly 80% of the respondents have completed higher education studies. About 53% of the respondents were aged 35 or younger, and about 64% had at least five years of work experience in the construction industry. When it comes to types of construction practitioners, more than 56% of the respondents were contractors, a quarter were construction management consultants, about 10% were designers, and 6% were clients.

Cronbach's alpha was used to test the reliability of the questionnaire. The alpha values for the understanding, utilisation, interest, and barrier subsections within the questionnaire are 0.951, 0.969, 0.927, and 0.858 respectively. All values are above 0.7 indicating that the questionnaire is reliable ([Henson, 2001](#)). [Table 5](#) presents the levels of understanding, utilisation, and interest of the respondents, and the relevance of the barriers according to their perceptions.

Table 4. Demographic profile of the respondents

Demographic	Classification	Count	Percentage
Gender	Male	87	72.50%
	Female	28	23.33%
	N/A	5	4.17%
Highest education	High School	4	3.33%
	Diploma	17	14.17%
	Undergraduate	86	71.67%
	Master	9	7.50%
	N/A	4	3.33%
Age	18-25	22	18.33%
	26-30	28	23.33%
	31-35	14	11.67%
	36-40	15	12.50%

Table 4. continued

Demographic	Classification	Count	Percentage
	41-45	18	15.00%
	46-50	7	5.83%
	51-55	9	7.50%
	56-60	3	2.50%
	N/A	4	3.33%
Type	Client organisations	8	6.67%
	Contractors	68	56.67%
	Construction Management Consultant	31	25.83%
	Design Consultant	13	10.83%
Years of experience	<5 years	35	29.17%
	5-10 years	42	35.00%
	11-15 years	16	13.33%
	>15 years	19	15.83%
	N/A	8	6.67%

Note: N/A means the respondents did not provide the information

Table 5. Levels of understanding, utilisation, interest, and barrier

Understanding			Utilisation			Interest			Barrier		
Code	Average	Rank	Code	Average	Rank	Code	Average	Rank	Code	Average	Rank
A1	3.35	2	A1	2.44	4	A1	3.57	2	E1	2.98	10
A2	3.06	7	A2	2.36	6	A2	3.51	3	E2	3.01	9
B1	3.06	7	B1	2.31	7	B1	3.33	8	E3	3.48	2
B2	3.13	5	B2	2.40	5	B2	3.48	5	E4	3.39	3
B3	3.15	4	B3	2.46	3	B3	3.44	6	E5	2.92	12
B4	2.90	9	B4	2.25	9	B4	3.32	9	E6	3.08	6
C1	3.23	3	C1	2.48	2	C1	3.51	3	E7	2.96	11
C2	2.70	10	C2	2.07	10	C2	3.29	10	E8	3.68	1
D1	3.53	1	D1	2.68	1	D1	3.81	1	E9	3.06	7
D2	3.08	6	D2	2.28	8	D2	3.40	7	E10	3.33	4
Total	3.12		Total	2.37		Total	3.47		E11	3.02	8
									E12	3.33	4
									Total	3.18	

LEVELS OF UNDERSTANDING, UTILISATION, AND INTEREST

As presented in [Table 5](#), the overall level of understanding is 3.12, indicating that the respondents only had a little level of understanding of the 10 drone functions. Making promotional videos has the highest average score at 3.53. Examining the results further, it seems that simpler drone functions for taking photos and videos, such as promotional marketing, final inspections of completed buildings, remote monitoring and progress reporting, and building inspection during construction, tend to have higher scores. On the other hand, the respondents tended to indicate a lower level of understanding of more complex drone functions. For example, in photogrammetry, additional skills and programs are needed if construction practitioners want to take pictures automatically on a planned flight route (autonomous navigation). In security monitoring, equipment and material monitoring, and surveillance, the analysing image process can be maximised with AI, which requires additional skills and programs. Likewise, the use of thermal sensors in drones also requires input from building thermal experts so that information can be interpreted and actioned appropriately.

The overall level of utilisation is 2.37, indicating that the respondents rarely used drones in their work. Matching their level of understanding, making promotional videos has the highest level of utilisation, which is understandable because drones for promotional marketing have been used fairly regularly not only in construction but also in other industrial sectors ([Bogue, 2018](#)). Likewise, simpler drone functions tend to be used more frequently than complex ones, which require additional skills, devices, and technologies for their optimum use.

The overall level of interest is 3.47, indicating a moderate-to-high level of interest. Construction practitioners have a high interest in the functions of making promotional videos, land surveys, photogrammetry for topographic mapping, and final inspections of completed buildings. However, their interests are at a moderate level in building inspection, remote monitoring and progress reporting, security monitoring, equipment and material monitoring, and building maintenance using thermal sensors. Although the level of interest is higher for simpler functions, the respondents were interested in photogrammetry for the topographic mapping function despite its relative complexity. The research found that the COVID-19 pandemic has accelerated changes in work patterns, from traditional ways of working to remote working supported by advanced technologies ([Merket and Bushnell, 2020](#)). It is interesting to see how the work patterns in the construction industry will evolve in the future. The interest in using drones, particularly for complex functions, may be an indicator of this change.

BARRIERS TO USING DRONES

The overall level of the 12 barriers is 3.18 (neutral). In other words, construction practitioners do not consider the barriers as something that is so inhibiting, although they cannot simply be neglected either. The highest-ranked barrier is the need for skilled human resources. To be able to operate drones optimally, particularly for complex functions, advanced skills are needed. The need to upskill human resources has been previously identified as a barrier to adopting new technologies in the construction industry ([Bello, et al., 2021](#)). Therefore, construction organisations that would like to embrace drone technology to improve their process need to provide necessary training or direct them to the right learning pathways.

Risks when using drones are the second highest risk. In developed countries, health and safety risk is a major concern in relation to drone usage ([Merket and Bushell, 2020](#); [Tal and Altschuld, 2021](#)). In this research, an open-ended question was included in the questionnaire, asking the respondents to identify concerns about using drones. The risks put forward by the respondents are the drone signal may be lost when approaching a tower crane, some areas have a poor signal, there are difficult terrains to control a drone-like around power lines, high maintenance cost, drone's battery drains quickly, weather conditions preventing its use, and privacy concerns.

Other barriers worth mentioning are limited drone technologies and features in the area, no government regulations on the use of drones in the construction industry, and again concerns related to the cost of using drones and their respective benefits.

LEVELS OF READINESS ACROSS DIFFERENT TYPES OF CONSTRUCTION PRACTITIONERS

Before conducting the analysis, it is important to test the normality and homogeneity of the data. The data are normal if the skewness is ranging from -2 until +2 and kurtosis is ranging from -7 until +7. The data are homogeneous if the Levene Test's significance level is above 5%. If the data are normal and homogeneous, one-way ANOVA can be used to identify significant differences among groups being investigated, i.e., contractors, construction management consultants (CM consultants), design consultants (designers), and clients. When a significant difference is found, a post hoc test can be performed to identify the source of that difference, i.e., which groups of respondents cause the difference. The Tukey test is used as a post hoc test when the data are normal and homogenous. When the data are normal but inhomogeneous, the Welch test (instead of ANOVA) should be performed to identify significant differences. In this situation, the Games-Howell test is the post hoc test to identify the sources of the differences ([Boadu, Wang and Sunindijo, 2021](#)).

[Table 6](#) presents the level of understanding among the four types of construction practitioners. Since the data are not homogenous, the Welch test was performed, and three significant differences were found (A1, B1, D1).

Table 6. Level of understanding among construction practitioners

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
A1*	3.21	1.02	3	3.87	1.02	2	2.85	1.21	2	3.38	1.51	2
A2	2.97	1.13	9	3.45	1.26	4	2.54	1.33	6	3.13	1.36	5
B1*	3.22	1.05	2	3.26	1.29	8	2.00	1.35	9	2.63	1.60	6
B2	3.19	0.93	4	3.35	1.11	6	2.62	1.45	5	2.63	1.77	6
B3	3.15	1.07	5	3.39	1.31	5	2.54	1.45	6	3.25	1.67	4
B4	3.01	0.97	8	2.97	1.35	9	2.38	1.33	8	2.50	1.69	9
C1	3.15	1.07	5	3.58	1.18	3	2.69	1.44	4	3.38	1.51	2
C2	2.84	1.11	10	2.74	1.29	10	2.00	1.29	9	2.50	1.51	9
D1*	3.28	1.10	1	4.06	0.89	1	3.31	1.44	1	4.00	1.20	1
D2	3.07	1.01	7	3.32	1.19	7	2.77	1.24	3	2.63	1.30	6
Total	3.11			3.40			2.57			3.00		

\bar{x} = mean, S = standard deviation, * = significant difference

Based on the Games-Howell post hoc test ([table 7](#)), CM consultants have a higher level of understanding than contractors in terms of land survey (A1) and promotional video (D1). The different roles of these two practitioners may be responsible for this result. In Indonesia, contractors mainly focus on

performing activities in the construction phase, while CM consultants have a wider range of involvement throughout all phases of construction (Nikumbh and Pimplikar, 2014). Performing land surveys and making promotional videos are, therefore, more relevant for CM consultants. Table 7 also shows that contractors and CM consultants have higher levels of understanding than designers on using drones for equipment and material monitoring (B1). This is understandable because it is not the responsibility of designers to manage and monitor site conditions.

Table 7. Games-Howell Post-hoc Test for the level of understanding among construction practitioners

Code	Practitioners		Mean difference	Sig.
Land surveys	Contractor	CM Consultant	-.66509*	0.02
Equipment and material monitoring	Contractor	Design Consultant	1.22059*	0.035
	CM Consultant	Design Consultant	1.25806*	0.043
Promotional videos	Contractor	CM Consultant	-.78510*	0.002

Table 8 presents the levels of drone utilisation among the four types of construction practitioners. The Welch test was again performed because the data were not homogeneous. Although the levels of utilisation are generally low, it is clear that designers in this research have never used drones in their work. This result is further confirmed by the Games-Howell post-hoc test presented in Table 9, which shows that designers' level of drone utilisation is significantly lower than contractors and CM consultants across all the drone functions.

Table 8. Level of utilisation among construction practitioners

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
A1*	2.59	1.30	5	2.77	1.41	3	1.15	0.55	1	2.00	1.51	3
A2*	2.47	1.26	8	2.77	1.38	3	1.15	0.55	1	1.75	1.49	7
B1*	2.51	1.29	6	2.52	1.26	7	1.00	0.00	7	1.88	1.46	5
B2*	2.63	1.27	2	2.61	1.23	6	1.08	0.28	5	1.75	1.16	7
B3*	2.60	1.26	3	2.77	1.50	3	1.15	0.55	1	2.13	1.55	2
B4*	2.47	1.15	8	2.42	1.43	9	1.00	0.00	7	1.75	1.16	7
C1*	2.60	1.29	3	2.90	1.30	2	1.15	0.55	1	1.88	1.25	5
C2*	2.35	1.13	10	2.00	1.15	10	1.00	0.00	7	1.63	1.19	10
D1*	2.75	1.31	1	3.19	1.47	1	1.08	0.28	5	2.75	1.67	1
D2*	2.49	1.20	7	2.45	1.06	8	1.00	0.00	7	2.00	1.51	3
Total	2.55			2.64			1.08			1.95		

\bar{x} = mean, S = standard deviation, * = significant difference

Table 9. Games-Howell Post-hoc Test for the level of utilisation among construction practitioners

Code	Practitioners		Mean difference	Sig.
Land survey	Contractor	Design Consultant	1.43439*	0
	CM Consultant	Design Consultant	1.62035*	0
Photogrammetry	Contractor	Design Consultant	1.31674*	0
	CM Consultant	Design Consultant	1.62035*	0
Equipment and material monitoring	Contractor	Design Consultant	1.51471*	0
	CM Consultant	Design Consultant	1.51613*	0
Inspection during construction	Contractor	Design Consultant	1.55543*	0
	CM Consultant	Design Consultant	1.53598*	0
Monitoring and progress reporting	Contractor	Design Consultant	1.44910*	0
	CM Consultant	Design Consultant	1.62035*	0
Worker surveillance	Contractor	Design Consultant	1.47059*	0
	CM Consultant	Design Consultant	1.41935*	0
Final inspection	Contractor	Design Consultant	1.44910*	0
	CM Consultant	Design Consultant	1.74938*	0
Maintenance using thermal sensors	Contractor	Design Consultant	1.35294*	0
	CM Consultant	Design Consultant	1.00000*	0
Promotional videos	Contractor	Design Consultant	1.67308*	0
	CM Consultant	Design Consultant	2.11663*	0
Security monitoring	Contractor	Design Consultant	1.48529*	0
	CM Consultant	Design Consultant	1.45161*	0

Except for D1, the Welch test found no differences among the construction practitioners when it comes to the level of interest in using drones as shown in [Table 10](#). This result implies that the Indonesian construction industry is showing a fairly high level of interest in using this technology at work. This is important because having an interest is the precursor of commitment to adopting new technologies.

Table 10. Level of interest among construction practitioners

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
A1	3.49	0.89	3	3.74	0.86	2	3.38	0.77	6	3.88	0.64	3
A2	3.43	0.95	6	3.61	1.17	3	3.54	0.78	3	3.75	0.71	5
B1	3.41	0.95	7	3.26	1.26	8	3.00	0.71	10	3.50	1.07	7

Table 10. continued

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
B2	3.56	0.85	2	3.29	1.24	7	3.46	0.97	4	3.50	1.51	7
B3	3.44	0.87	4	3.32	1.40	6	3.46	1.05	4	3.88	0.83	3
B4	3.38	0.88	8	3.19	1.25	10	3.23	0.93	9	3.38	1.30	9
C1	3.44	0.89	4	3.58	1.26	4	3.38	0.87	6	4.00	0.76	2
C2	3.28	1.03	10	3.23	1.26	9	3.31	1.25	8	3.63	0.92	6
D1*	3.60	0.88	1	4.13	0.85	1	3.77	0.83	1	4.38	0.92	1
D2	3.37	0.90	9	3.39	1.12	5	3.69	0.75	2	3.25	0.89	10
Total	3.44			3.47			3.42			3.71		

\bar{x} = mean, S = standard deviation, * = significant difference

The Games-Howell post-hoc test (Table 11) revealed that CM consultants have a higher level of interest than contractors in using drones for making promotional videos (D1), and this result matches the result on the level of understanding. As explained previously, the wider scope of work of CM consultants may drive them to use drones for promotional marketing purposes.

Table 11. Games-Howell Post-hoc Test for the level of interest among construction practitioners

Code	Practitioners		Mean difference	Sig.
Promotional videos	Contractor	CM Consultant	-.52609*	0.031

Except E2, ANOVA test revealed no significant differences in the opinions of the four types of construction practitioners in relation to the barriers to using drones, indicating the widespread nature of the barriers across the industry. Tukey's post-hoc test (Table 13) only revealed one significant difference, in which contractors felt more strongly than designers that the rapid change in drone technology (E2) is a barrier to their adoption. The lack of drone utilisation among designers may be responsible for this difference as designers may not be aware of the latest developments in drone technology.

Table 12. Barriers according to construction practitioners

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
E1	2.99	0.80	10	2.87	0.81	9	2.77	0.83	10	3.63	0.52	4
E2*	3.18	0.91	6	2.87	0.88	9	2.38	0.87	12	3.13	0.99	8
E3	3.34	0.87	3	3.71	0.97	1	3.38	0.87	4	3.88	0.83	1
E4	3.43	0.92	2	3.35	1.08	3	3.08	0.86	7	3.75	0.89	2
E5	3.03	1.21	9	2.77	0.84	11	2.69	0.85	11	2.88	0.83	11

Table 12. continued

Code	Contractor			CM consultant			Designer			Client		
	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank	\bar{x}	S	Rank
E6	2.99	1.22	10	3.16	0.90	6	3.23	0.73	6	3.25	1.04	7
E7	2.78	1.08	12	3.06	0.89	7	3.54	0.88	3	3.13	1.36	8
E8	3.68	0.94	1	3.65	1.02	2	3.69	0.75	1	3.75	1.04	2
E9	3.16	1.18	7	2.97	1.02	8	2.85	0.99	9	2.88	1.25	11
E10	3.34	0.89	3	3.23	0.84	4	3.38	0.65	4	3.63	0.92	4
E11	3.16	0.92	7	2.74	1.00	12	2.92	0.86	8	3.00	0.93	10
E12	3.31	0.95	5	3.23	0.96	4	3.62	1.04	2	3.50	0.76	6
Total	3.20			3.13			3.13			3.36		

\bar{x} = mean, S = standard deviation, * = significant difference

Table 13. Tukey Post-hoc Test for the level of barriers among construction practitioners

Code	Practitioners	Mean difference	Sig.
Drone technology is changing rapidly	Contractor Design Consultant	.79186*	0.024

RELATIONSHIPS BETWEEN DRONE READINESS DIMENSIONS

Pearson's correlation was used to establish these relationships. The correlations between levels of understanding, utilisation, and interest, are presented in [Table 14](#). There are positive and significant correlations across all 10 drone functions, which can be surmised that increasing the awareness and understanding of construction practitioners is the key to increasing the levels of interest and utilisation of drones in the Indonesian construction industry. Research has found that awareness is the foundational factor in adopting new approaches to promote improvements ([Zou and Sunindijo, 2013](#)).

Table 14. Correlations among dimensions of drone readiness

Code	Understanding & interest		Interest & utilisation		Understanding & utilisation	
	Correlation	Significance	Correlation	Significance	Correlation	Significance
A1	0.486	0.000	0.346	0.000	0.553	0.000
A2	0.518	0.000	0.278	0.002	0.649	0.000
B1	0.448	0.000	0.515	0.000	0.651	0.000
B2	0.590	0.000	0.400	0.000	0.589	0.000
B3	0.624	0.000	0.417	0.000	0.621	0.000
B4	0.612	0.000	0.428	0.000	0.605	0.000
C1	0.627	0.000	0.410	0.000	0.615	0.000

Table 14. continued

Code	Understanding & interest		Interest & utilisation		Understanding & utilisation	
	Correlation	Significance	Correlation	Significance	Correlation	Significance
C2	0.621	0.000	0.302	0.001	0.655	0.000
D1	0.752	0.000	0.410	0.000	0.496	0.000
D2	0.552	0.000	0.293	0.001	0.563	0.000

Further correlation analyses were conducted between levels of interest and utilisation, and barriers to using drones with an assumption that tackling specific barriers is a way to increase interest in drones and their utilisation. In the analyses, particular attention was given to negative and significant correlations, which indicate that a reduction in a barrier can increase levels of interest and utilisation. Two such correlations are presented in [Table 15](#).

Table 15. Correlations between level of interest and barriers

Interest	Barrier	Correlation	Significance
Worker surveillance (B4)	Current technology and construction methods are still relevant, without using drones (E1)	-0.197	0.031
Promotional videos (D1)	Limited information of drone suppliers (E11)	-0.243	0.007

First, interest in using drones for worker surveillance correlates negatively with current methods is still relevant without using drones. Conventional methods to monitor workers, such as inspection, are still deemed effective, thus negating the interest in using drones for the same purpose. Second, using drones for making promotional videos correlates negatively with limited information about drone suppliers. This drone function already has the highest levels of understanding, interest, and utilisation among Indonesian construction practitioners. It seems that the lack of information about drone suppliers limits the widespread adoption of this drone function in the Indonesian construction industry. Once the technology becomes more accessible, the popularity of this particular function will increase further.

Correlations between the level of utilisation and barriers are shown in [Table 16](#). Limited information about drone suppliers and the potentially high cost of using drones seem to be the main barriers to using drones, particularly for functions like inspection, monitoring and reporting, surveillance, and making promotional videos. It is possible that these two barriers are related. There may be a lack of understanding of the cost-benefit of using drones due to the limited number of drone suppliers. This lack of information makes construction practitioners perceive that using drones is costly, especially when their benefits have not been investigated ([Poikonen and Campbell, 2020](#)). The added cost has been seen as a hindrance in adopting new technologies in construction due to the low profit margin in the sector ([Bello, et al., 2021](#)).

PROMOTING DRONE APPLICATION IN THE INDONESIAN CONSTRUCTION INDUSTRY

Based on the above data analysis, the following strategies are proposed to promote the application of drones in the Indonesian construction industry. First, there is a need to create a sense of urgency by identifying the need for change by examining and reviewing the market environment, potential threats and major benefits. This is an initial step for leaders to reduce resistance to change and motivate employees to embrace change

Table 16. Correlations between the level of utilisation and barriers

Utilisation	Barrier	Correlation	Significance
Building inspection during construction (B2)	The costs are not comparable with the benefits (E12)	-0.264	0.004
Remote monitoring and progress reporting (B3)	Limited information of drone suppliers (E11)	-0.228	0.012
Remote monitoring and progress reporting (B3)	The costs are not comparable with the benefits (E12)	-0.23	0.012
Worker surveillance (B4)	The costs are not comparable with the benefits (E12)	-0.234	0.010
Promotional videos (D1)	Limited information of drone suppliers (E11)	-0.227	0.013
Promotional videos (D1)	The costs are not comparable with the benefits (E12)	-0.195	0.033

by delivering a message that creates the proper sense of urgency to change (Kotter, 1995). Underpinned by this sense of urgency, practitioners will understand the reasons for and advantages of adopting drone technology (Lavikka, et al., 2018).

Second, organisational talent development is emphasised in the organisational management literature to facilitate change (Aina and Atan, 2020; Michaels, Handfield-Jones and Axelrod, 2001). In the digital age, talent development is a means to enhance and build an organisation's digital technology capability (Aian and Atan, 2020; Wu and Issa, 2014). The knowledge and skills of digital talents can be transformed into the organisation's tacit knowledge to enhance the organisation's adaptability in the digital age (Pathirage, Amaratunga and Haigh, 2007). For the Indonesian construction industry, developing talents by recruiting new employees or upskilling existing ones is valuable to promote the application of new technology. This may be beneficial in two parts. First, as mentioned in the 'barriers to using drones' section, Indonesian construction organisations need to develop drone professionals to fully utilise the capabilities of drones and achieve the desired benefits. Second, drone talents can act as organisational change champions. They participate in technological change as grassroots employees, share information with colleagues, and use their drone knowledge and understanding to motivate and lead colleagues to participate in the adoption of drone technology (Wilson and Mergel, 2022; Ernstsen, et al., 2021).

The findings provide guidance for promoting the use of drone technology in the Indonesian construction industry, allowing participants from different construction organisations to develop targeted solutions to increase their readiness. For example, a series of seminars or workshops can be held to increase construction practitioners' understanding of drone technology. This is important as the lack of understanding may hinder them from attempting to use drones in the first place (Morgan and Papadonikolaki, 2022). Using drone technology in a pilot project may also increase their levels of understanding and awareness and encourage them to use the technology in their future projects. Managers, however, should be made aware that it may not be possible to immediately reap the benefits of applying new technology. A gradual approach to using drones is advisable to find the right drone functions that suit certain construction organisations (Bolpagni, 2022). Lastly, as stated in the findings, conducting a cost-benefit analysis and demonstrating the risks and rewards of using drones can help construction practitioners develop strategies to minimise the risks while optimising the benefits when implementing drone technology in their organisations (Lu, et al., 2014).

Conclusions

This research aims to understand the readiness of drone applications in the Indonesian construction industry. Four interrelated dimensions, including understanding, interest, utilisation, and barriers, have been assessed to measure this level of readiness. This research found that there is a moderate-to-high level of interest in using drones. However, the level of understanding among Indonesian construction practitioners is still rather low, which is also manifested in the low level of drone utilisation in the industry, particularly for more complex functions besides taking photos and videos. Among different types of construction practitioners, the level of utilisation among designers is the lowest, although they still display a considerable level of interest in their potential use in the industry. Based on the above findings, increasing the level of understanding and awareness of drone technology is a way to increase the level of drone utilisation in the Indonesian construction industry.

Increasing drone utilisation can also be achieved by removing barriers that hinder the adoption of this technology. Lack of skilled human resources and risks associated with the use of drones are the two highest-ranked barriers according to the respondents. They indicate the need to increase drone understanding and awareness so that construction practitioners are equipped with adequate skills to utilise drones and their risks effectively. The perceived high costs of using drones and limited information about drone suppliers seem to be other barriers that prevent construction practitioners from adopting this technology in the first place. More information on drone technology and cost-benefit analysis across drone functions are needed to encourage its use in the Indonesian construction industry.

There are several research limitations and associated recommendations for future research worth mentioning. First, Indonesia is a large archipelago country, and data were collected from a large city in Java, an island considered to be the most developed in Indonesia. These findings, therefore, may not reflect the conditions in less developed areas in the country. Future research can study the influence of geographical locations and drone readiness. Second, understanding the influence of demographic profiles of construction practitioners on drone readiness is another interesting factor to be considered. This understanding can be used to tailor intervention strategies to encourage different practitioners to adopt the technology. Third, the quantitative methodology adopted in the current research is useful for obtaining a general overview of drone readiness. Future research can adopt qualitative methodology by collecting data using interviews to get a deeper understanding of the issues that prevent the adoption of this technology in Indonesia. Fourth, purposive sampling was used, so the results should be interpreted carefully. However, this research is important because there is a lack of research that investigates drone readiness in the Indonesian construction industry. The approaches used in this research, therefore, can be used in future research to get a deeper understanding of this phenomenon.

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