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AN INVESTIGATION OF THE IMPLICATIONS OF COVID-19 FOR DIGITALISATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

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Abstract

The construction industry has a reputation for being the least digitalised industry and the outbreak of COVID-19 pandemic have further accelerated the move of digitalisation in the construction practices. However, there is still a lack of studies to examine the extent of digitalisation brought by the pandemic. Therefore, this paper aims to investigate the implementation status of various digital technologies in the Malaysian construction industry during and after COVID-19. This paper also examines if the COVID-19 has created a sense of urgency around digital transformation in the Malaysian construction industry. A questionnaire survey was carried out with 95 respondents from different construction professions. The results showed that COVID-19 has significantly boosted digital practices among Malaysian construction firms but there is a disproportionate adoption in rural areas as well as small and medium sized enterprises (SMEs), further widening the digital divide in Malaysia. The findings suggest that the adoption of cloud computing, mobile computing and building information modelling (BIM) is accelerated significantly after COVID. The findings showed that the digitalisation awareness and the implementation of various digital tools in the Malaysian construction industry have been generally increased, showing a readiness of the construction industry in transition to digitalisation. However, more efforts are needed to bridge the digital divide to ensure no one will be marginalised in the future digital initiatives.

Keywords: Construction Industry, COVID-19 Pandemic, Digitalisation, Digital Technologies, ,

1. Introduction

Industrial Revolution 4.0 (IR4.0) has been diffused into the market of most industries, including construction [1]. In Malaysia, a five-year Construction Strategic Plan 4.0 (2021 – 2025) has been developed by the Minister of Works and the Construction Industry Development Board (CIDB) to transform the Malaysian construction landscape into a smart and sustainable sector, positioning Malaysia as a market leader in Southeast Asia through digitalisation [2].

Digitalising the construction process can benefit the construction industry in a multitude of ways by revolutionising and revitalising the slow and old-fashioned construction sector [3]. According to Jacobsson and Linderoth [4], a successful application of digital technologies in construction can help the sector enhance efficiency, reduce uncertainties and unsatisfactory outputs, build better, and address a variety of inherent issues such as labour productivity, labour shortages, carbon emissions, and waste.

Despite the well-documented benefits of construction digitalisation, the readiness for digital transformation in the construction industry is still in its infancy when compared to other sectors [5]. The construction industry is one of the least digitalised sectors in the economy [6, 7] and it has long been reputed as "behind the times" or the "last living dinosaur" [8]. This is no exception in Malaysia, where the Malaysian construction industry has yet to fully embrace digitalisation in service delivery [9]. Falling behind in the digital move, the productivity in construction is found declining, although the construction workforce is reported shrinking at the same time.

However, there has been a change in the uptake of digital technologies in construction following the outbreak of Coronavirus Disease 2019 (COVID-19), a worldwide health crisis and infectious disease. Numerous research studies [7, 10-14] found that the COVID-19 crisis offers a new window of opportunity to accelerate the digital transformation in the construction industry. Umar et al. [15] stated that the COVID-19 crisis has caused a significant surge in the use of digital technology in the Malaysian construction industry to overcome the COVID-19 challenges and compensate for the drawbacks of lockdowns and safety protocols.

Literature identified main challenges arisen from COVID including travel bans, physical distancing measures, limited working capacity, increased health and safety protocols, mandatory site closure, lack of manpower supply, and materials supply disruptions [7, 15, , 16]. Ebekozien and Aigbavboa [7] described that construction projects had confronted various movement restrictions, physical distancing, lockdowns, remote working and strict health and safety protocols in the face of COVID, and digital technologies have become more pertinent to mitigate the COVID risks. Raoufi and Fayek [16] also identified material supply chain interruptions, labour shortage, limited work capacity, physical distancing, increased hygiene protocols and reduced productivity as main challenges and they highlighted the importance of using digital technologies to control and mitigate the adverse effects of COVID-19. Likewise, Cheshmehzangi [17] articulated that during the COVID-19 outbreak, the Malaysian construction industry underwent a paradigm change toward digitalised approaches that are more interactive, integrated, and information-based in order to sustain business operations and address various onset and unforeseen uncertainties caused by COVID-19.

Nonetheless, Prinatih [18] and BusinessToday [19] contend that COVID-19 has only accelerated the digitalisation of 25% of construction organisations in Malaysia. Likewise, Amoah et al. [20] also observed that such acceleration rate is uneven and is in a manner that brings paradoxes and contradictions to the digital transformation in construction. Although the COVID-19 pandemic offers copious opportunities for construction firms to embrace digitalisation, digital transformation might not be sped up as expected, especially for small and medium-sized enterprises (SMEs) in construction. This shows a discrepancy between large enterprises and SMEs in responding to the implications of COVID-19 to enhance their digital dynamics in the business operations, resulting persistent digital divides among construction businesses in Malaysia.

Furthermore, there has been a lack of studies to investigate digital diffusion and uptake across construction businesses in the age of COVID-19. Some literature attempted to investigate the adoption of digital technology in the construction industry. For example, Umar et al. [15] indicate that there was a significant surge in deploying digital technologies in Malaysian construction industry after the COVID-19 crisis. Similarly, Cheshmehzangi [17] also found a paradigm shift towards digitised methods that are interactive, integrated, and information-based in Malaysian construction industry during the COVID-29 outbreak. In the meanwhile, Zakaria and Singh [21], Ebekozien and Aigbavboa [7], and CIDB [22] held those digital technologies such as drones, cloud computing, virtual reality (VR), tracing apps, and augmented reality are evolving at a fast rate to address various onset and unknown uncertainties created by COVID-19.

Nevertheless, the literature do not specify the extent to which different digital technologies are adopted in the Malaysian construction industry during and after the pandemic. Given these circumstances, further research is needed to fill the gaps by examining the prevalent situation of digitalisation in the Malaysian construction industry during and after COVID-19 to examine the implications of COVID in the uptake of digital technologies.

2. Digitalisation in Construction

According to Merrill [23], digitalisation in construction is the implementation of digital technologies to leverage the power of data to make construction operations more productive, efficient, and safe. In today's construction market, there are a variety of digital technologies and tools. The wide spectrum of construction digital technologies can be grouped into four main categories: digital data, connectivity, automation, and digital access [24-26].

2.1 Digital Data Technologies

Digital data technologies refer to digital technologies that can generate, collect and analyse data in order to acquire new insights into each link in the value chain and put them into a good use [27]. Examples of digital technologies in this category include sensors, radio-frequency identification (RFID), and drones [28]. These technologies serve as collection tools of digital data in construction. This type of technologies is regarded as the foundation of digitalisation as they provide key information for data development and building the entire digital construction ecosystem.

2.2 Connectivity Technologies

Connectivity related digital technologies are used to enhance connectivity and collaboration between major stakeholders using construction technology solutions. An example of connectivity technologies is the use of Building Information Modelling (BIM) to collaboratively design, build, and operate a building using a single coherent system in the 3D models rather than separate design drawing files and applications. BIM also allows for the exchange of vast amounts of information with other parties involved, allowing for a more integrative, synchronised, and collaborative project delivery. As described by Craveiro et al. [28] added that connectivity technologies might also be useful to link the physical-to-digital and digital-to-physical in construction such as augmented reality (AR) and VR.

2.3 Automation Technologies

Automation refers to digital technologies performing specific construction tasks autonomously without much human interventions. No extensive human labour or inputs are required to perform tasks, with the aid of automation technologies [29]. Some instances of automation technologies include self-organising robots, 3D printers that create building parts/components based on BIM or computer-aided design (CAD) files under the control of a computer [30], and blockchain enabling auto-execution of payments to suppliers or contractors [31].

2.4 Real-time Access Technologies

Real time access technologies are digital technologies afford users access to internet networks to execute tasks in real time, regardless of time and physical locations. Users can use this type of technologies making on-the-spot decisions or making predictions of future project performance [32]. Examples of the technologies include internet of things (IoT), mobile computing, cloud computing, artificial intelligence (AI), and big data analytics [33-34].

2.5 Digitalisation in Practice

Despite the rapid development of digital technologies in the market, the construction industry in Malaysia has yet to comprehensively integrate digital technologies into its service delivery [5-6, 9, 35]. BusinessToday [36] indicated that only a handful of construction companies in Malaysia implement BIM in their practices although BIM is considered to have a wider application amongst the prevalent construction digital technologies. Recent news reported by Rafee [37] stated that the BIM adoption level in Malaysia is only 17%, compared to 71% in US, 38% in UK, and 65% in Singapore. This can be inferred that the digitalisation in the Malaysian construction industry is still in the beginning stage.

The adoption pace of other digital technologies appears to be less promising too. Blanco et al. [38] reported that only limited engineering and construction firms in Malaysian construction industry are capable to implement AI technologies. Meanwhile, drones are considered to be far from the cutting-edge in the Malaysian construction industry [39]. Agus et al. [40] also revealed that the IoT adoption in the Malaysian construction industry is still slow in comparison to other Asian regions such as Hong Kong, Korea, China, and Singapore. In sum, all these solidified the maturity of digitalisation in the Malaysian construction industry is relatively low compared to other countries, even though the construction industry has been widely recognised as the least digitalised sector.

3. Methods

The study used a quantitative approach to investigate the adoption of various digital technologies in the Malaysian construction industry. A questionnaire survey was employed for the study because it is particularly useful to collect massive data from a large audience to give an overview of the digitalisation status in the Malaysian construction industry. Unlike interviews, a survey can gather data from a large group of respondents with varied backgrounds, increasing the reliability of the collected data and allowing the generalisation of local construction players' perceptions and attitudes.

In this study, the targeted population included all the construction industry players such as architects, quantity surveyors, engineers, developers, contractors, project managers, and site personnel in Malaysia, as they are best acquainted with its current state of the digital moves in the construction industry. A total of 752 questionnaires were distributed to the respondents using a simple random sampling method. The simple random sampling method was employed to remove unintentional bias using a similar sample population, making the generalisation of the study. The simple random sample can also reduce choreographed responses and counter check the responses to ensure the credibility of this study.

The data was collected in between 7 March 2022 and 21 March 2022. Malaysia was reported to have a very high number of COVID cases in this period, but the government had eased the COVID related restrictions to transition to the endemic phase on 1 April 2022 [41]. A total of 95 valid responses were received, giving a response rate of 12.63%. According to Fosnacht et al. [42], data remains reliable even with a response rate of 5%-10% if a sample size exceeds 500.

The collected data was then analysed using descriptive statistical analysis such as frequency, means and standard deviations. A Likert scale of 4-point and 5-point was used in the questionnaire to measure the adoption state of digital technologies and quantity the belief, opinions, judgements and preference of respondents. Mean scores of each construct in Likert scale are calculated by summating individual's score divided by the number of responses constituting the scale. In this study, all constructs comprising a scale are assumed to have equal weight when calculating a summated score or a mean score.

4. Results and Discussion

4.1 Respondent Demographics

The respondents consist of construction stakeholders from different trades and professions. Civil and structural engineers account for the majority of the survey respondents (58%), followed by quantity surveyors (13%), project managers (12%), architects (5%), contractors (3%), and other construction professionals (1%). Others include claims consultants, environmental engineers, innovation managers, land surveyors, offshore construction superintendents, planning engineers, project engineers, safety and health officers, and traffic engineer and transport planners, as shown in Fig. 1.

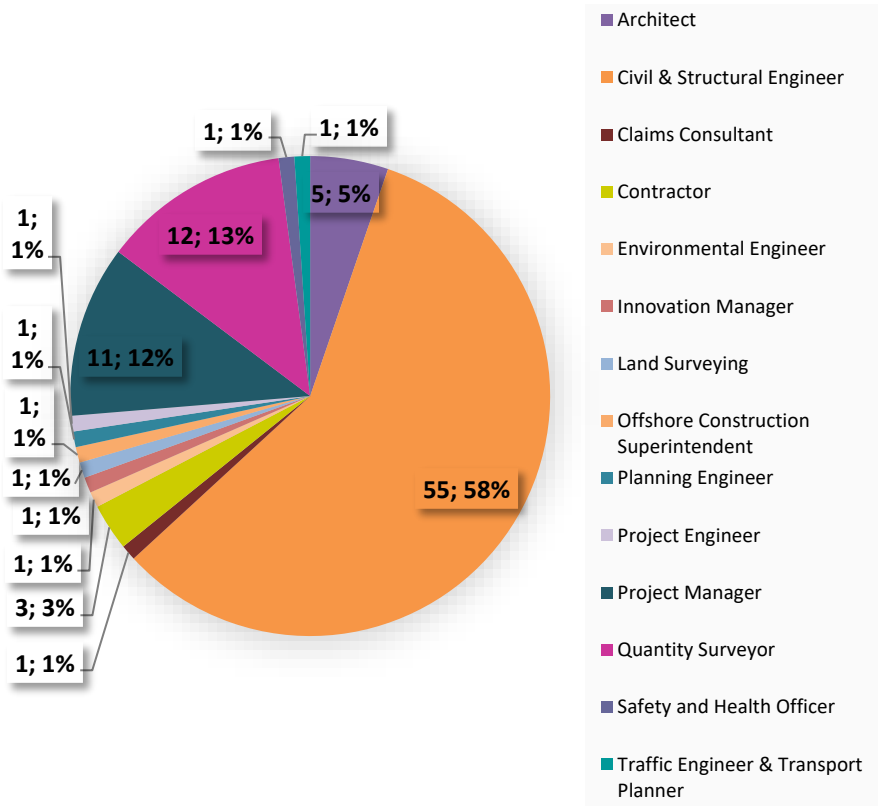

Fig. 1. Respondents Demographics

A majority of respondents (89%) hold executive and managerial positions in their companies. This shows that most respondents play a key role in either the company decision making or strategic execution. They have direct involvement in the company overall operation and are alert to the organisation digital moves. About 46% respondents have more than 20 years of work experience followed by less than 5 years (19%), 11-20 years (18%), and 5-10 years (17%). Over 60% respondents have worked in the construction field for more than 10 years. The extensive experiences possessed by the respondents could give better insights into the studied subject topics by examining the digital moves in construction over the years, hence increasing the reliability of the collected data.

4.2 The Adoption of Digital Technologies in the time of COVID-19

Figure 2 showed that 67% of respondents' companies have introduced new digital technologies or expanded the use of digital technologies to counteract the COVID-19-related challenges.

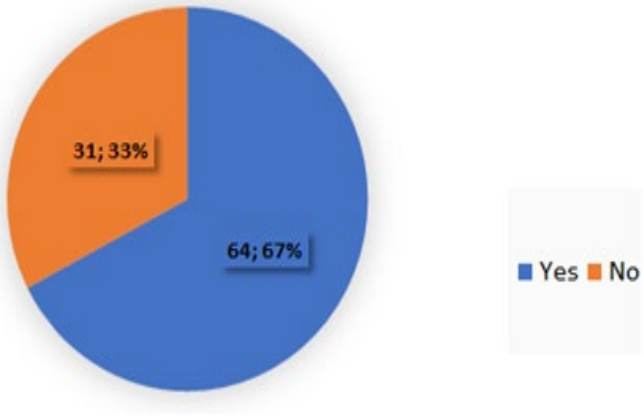

Fig. 2. The Adoption Rate of Digitalisation in Malaysian Construction Industry During and Post COVID-19

This suggests that COVID-19 has significantly boosted digital practices among Malaysian construction industry firms. The findings are aligned with other studies [10, 14-17] that also acknowledged the pandemic as a catalyst of digital transformation. Raoufi and Fayek [16] identified technology has the greatest rise in ranking in action prioritisation during the pandemic, in which "accelerate the update of digitalisation" and "increased contactless operations using new technology" gained greater impact ratings. COVID-19 forced construction companies to move rapidly in digitalisation, a result arising from various constraints on face-to-face business operations to curb the spread of the virus.

When cross-examining the results with the respondents' company size and location, the study found that the acceleration of digitalisation in construction companies with lesser than 50 employees is not significant. The impacts of COVID-19 on digitalizing the construction industry are disproportionate. Besides, the rate of digitalisation in East Malaysia is also found to be slower than the adoption of digital works in West Malaysia. These findings indicate that the company size and the location are the main factors influencing the digital transformation in construction. Construction companies located in rural areas and small and medium-sized enterprises (SMEs) are comparatively slow in their capabilities for a smooth digital transformation during and after COVID-19.

The results concur with the previous studies [14-17, 43] that the impacts of COVID-19 have more damaging impacts to SMEs due to a lack of resources, skills, infrastructure, and capitals for digital transformation. Bai et al. [43] described that digital transformation as a managerial issue rather than technical issue, particularly many rural organisations and SMEs know little of digitalisation. Digitalisation demands acquiring and deploying technical resources, redesigning business models and process, strengthening data communication structure as well as improving the organizational capability [7]. The stark differences in the acceleration of digitalization brought by the pandemic exacerbate the inequalities and further the

digital divide between urban and rural areas as well as between those giants and small and medium-sized businesses. The results are summarised in Tables 1 and 2.

Table 1. Company Location of respondents that have and have not accelerated digitalisation as a result of COVID-19.

Acceleration of Digitalisation due to COVID	Yes	No	% Yes
West Malaysia	48	19	71.64%
East Malaysia	16	12	57.14%

Table 2. Company size of respondents that have and have not accelerated digitalisation as a result of COVID-19.

Acceleration of Digitalisation due to COVID	Yes	No	% Yes
Company size less than or equal to 50 persons	22	20	52.38%
Company size more than 50, but less than and equal to 100 persons	8	3	72.73%
Company size more than 100 persons	34	8	80.95%

To gain further insights into digital diffusion, a follow-up question was asked to investigate the extent of various digital technologies deployed in the Malaysian construction industry. BIM is the most widely deployed technology during and after the pandemic, with a 39% adoption rate. This is followed by cloud computing (38%), mobile computing (31%), drones (25%), IoT (21%), sensors (15%), big data analytics (11%), VR (7%), AR (6%), 3D printing (5%), RFID (4%), and autonomous robots (2%). Blockchain appears to be underdeveloped as none of the respondents used blockchain during and post the pandemic. Figure 3 shows the state of adoption of different technologies in the Malaysian construction industry.

The results support Ebekozien and Aigbavboa [7]'s findings that simulation and modelling technologies such as BIM are helpful to assist construction players complying with the COVID rules of physical distancing and virtual meetings. Mobile computing and cloud computing can help enhance compliance to COVID regulations and keep the work on going, despite in quarantine or self-isolation [7].

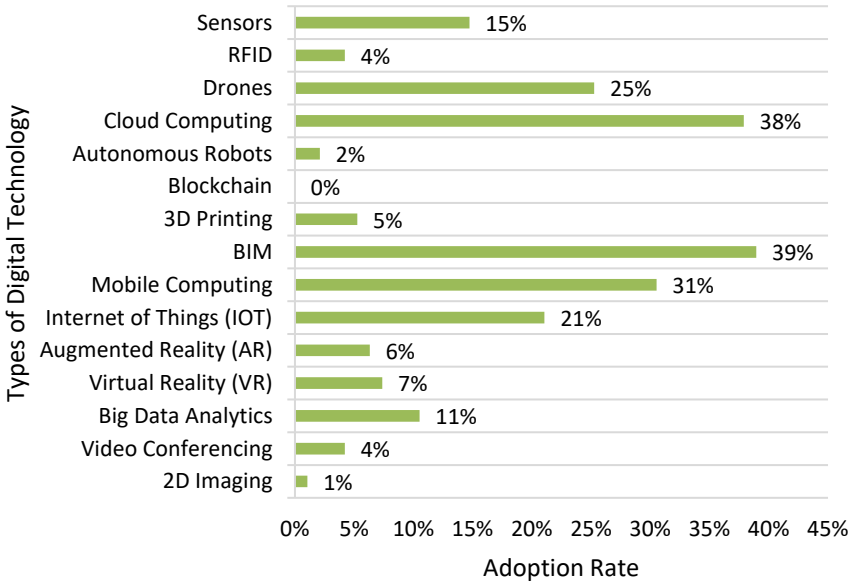

Fig. 3. The adoption of different digital technologies in the Malaysian construction industry.

Although BIM has the highest degree of adoption during and after the pandemic, cloud computing was found to have the fastest growth rate as a result of COVID-19, followed by mobile computing, BIM, drones, sensors, IoT, big data analytics, VR, AR, 3D printing, autonomous robots, blockchain, and RFID. Table 3 ranks the deployment of varying digital technologies by considering their mean score.

Table 3. A comparison of the adoption state of digital technologies before and during the COVID-19 crisis.

Digital Technology	1	2	3	4	Mean score	Rank
Cloud Computing	10	14	28	12	2.66	1
Mobile Computing	11	14	29	10	2.59	2
BIM	17	17	19	11	2.38	3
Drones	21	19	18	6	2.14	4
Sensors	34	10	11	9	1.92	5
IoT	33	11	17	3	1.84	6
Big Data Analytics	41	6	9	8	1.75	7
VR	43	4	12	5	1.67	8
AR	45	7	7	5	1.56	9
Autonomous Robots	46	7	5	6	1.55	10
3D Printing	49	3	8	4	1.48	11
					1.48	
Blockchain	50	3	5	6	1.48	11
RFID	50	4	3	7	1.48	11

[1] **Never use even during the crisis.**

[2] Used prior to the crisis, but the adoption rate has remained unchanged even during the crisis[3] Used prior to the crisis, and was expanded during the crisis as a result of COVID-19
[4] First time use to counteract challenges posed by COVID-19

Profound changes and restrictions resulting from COVID-19 have pushed construction businesses to embrace digital innovations to ensure business continuity. The study also scrutinised varying COVID-19 disruptions that has led to the rise of deployment of digital technologies in construction. The main COVID-19 pandemic challenges to the adoption of digitalisation in their organisations are identified in Table 4. The most significant challenge brought by the COVID crisis is travel bans, followed by physical distancing measures, limited working capacity, increased health and safety protocols, mandatory site closure, lack of manpower supply, and materials supply disruptions. These COVID related disruptions caused a structural shift in the business operating models, hence increasing the pace of digitalisation in the construction sector.

Table 4. COVID disruptions that help catalyse digitalisation in the Malaysian construction industry.

COVID-19 Challenges	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Mean Score
Travel Bans	1	8	20	50	16	95	3.76
Physical Distancing Measures	1	6	23	51	14	95	3.75
Limited Working Capacity	1	7	21	55	11	95	3.72
Increased Health and Safety Protocols	1	12	24	45	13	95	3.60
Mandatory Site Closure	4	12	27	35	17	95	3.52
Lack of Manpower Supply	2	12	33	38	10	95	3.44
Materials Supply Disruptions	3	17	31	36	8	95	3.31

On the other hand, the COVID-19 pandemic has led to an increased awareness of technological adoption for digitalisation in construction. Approximately 74% respondents either strongly agreed or agreed that digital technology is a more fitting method than the traditional method in respond to COVID-19 challenges, while only 26% respondents hold a neutral position. In addition, around 73% respondents agreed that adopting digital technologies in construction earlier would have helped the industry to be more prepared for the COVID-19 pandemic with a mean score

of 4.03. Early adoption of technologies help increases organisation's ability to go digital in a short period, hence improving their resilience to adapt and succeed in the post COVID-19 world. It also reflects that the awareness of the Malaysian construction organisations towards digitalisation has grown following COVID-19. The results are presented in Tables 5.

Table 5. Fitness of digitalisation in a COVID-19 world.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total	Mean Score
Digital technology is a more fitting method than traditional in a COVID world.	0	0	25	39	31	95	4.06
Adopting digital technologies in construction earlier would have helped the industry to be more prepared for the COVID-19 pandemic.	1	2	23	36	33	95	4.03

5. Conclusions

Despite technological innovations and advancements, the pace of digitalisation is still not encouraging in the Malaysian construction industry, but the wake-up call from COVID-19 could have turned things around.

COVID-19 pandemic wreaked havoc on the Malaysian construction industry. As a result, the urgency of the Malaysian construction industry's digital transformation has heightened, and the digitalisation in the industry has been accelerated. A majority of the Malaysian construction industry players adopted new digital technologies and expanded the digital technology usage in their practice. The rate of digitalisation in the Malaysian construction industry during and after COVID-19 is greater than the period before COVID-19. s.

The findings showed that COVID-19 accelerated the adoption of cloud computing in the Malaysian construction industry greatly, having the most significant growth. This is followed by mobile computing, BIM, drones, sensors, IoT, big data analytics, VR, AR, 3D printing, autonomous robots, blockchain, and RFID. BIM is

the most widely adopted while blockchain is the least adopted digital technology. Travel bans challenge has been identified as the most influential disruption event that accelerating digital technology adoption among the COVID-19 challenges.

The COVID-19 crisis has clearly shed light on the acceleration of the implementation of digitalisation in the Malaysian construction industry. Because of COVID-19, the awareness of Malaysian construction industry players towards digitalisation has also been raised, showing the readiness of the construction industry towards digitalisation.

However, the study found that the acceleration of digital technologies is disproportionate, and the digital divide remains in the Malaysian construction industry. Construction companies in East Malaysia and smaller size companies are found to embrace digitalisation at a slower rate than those in West Malaysia and giant companies in the industry, due to the human resources and capability impediments. These results suggest that more efforts shall be put to bridge the digital divide in the future digital initiatives, rather than focusing to raise up the overall digitalisation level in the industry. This is important to ensure that the benefits of digitalisation can be maximised and no one in the Malaysian construction industry is left out.

The study has some limitations. Due to resources and time constraints, this study has a relatively small sample size. Although the data collected remains reliable and credible, future studies should reach a wider range of construction organisations and investigate varying levels of digitalisation brought by COVID to organisations with different sizes, locations and characteristics.

The contributions of this paper are: 1) identifying the implications of COVID in digitalising construction practice in Malaysia; 2) offering insights into the states of digitalisation in construction in Malaysia during and after the COVID crisis; 3) identifying the extent of different digital technologies adopted in the construction industry and 4) determining if the digital divide remains during and after the COVID pandemic. Future works may explore the impacts of COVID on digitalisation in-depth using longitudinal research. In addition, future studies can also evaluate the effects and effectiveness of deploying different digital technologies in transforming the construction business operation models. This paper contributes to the existing literature in relation to the COVID effects and digitalisation in construction. By understanding the implications of COVID in the prevalent digital initiatives, industry stakeholders can rethink their core competence to anticipate the technological changes in transition to digitalisation.

Abbreviations

AI	Artificial Intelligence
AR	Augmented Reality
BIM	Building Information Modelling
CAD	Computer-Aided Design
CIDB	Construction Industry Development Board
COVID-19	Coronavirus Disease 2019
IoT	Internet of Things
IR4.0	Industrial Revolution 4.0

RFID	Radio-Frequency Identification
SMEs	Small and Medium Enterprises
VR	Virtual Reality

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