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Digitalization: Potentials of Digital Technology Capabilities in the Construction Industry

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ABSTRACT

Digital technology is an essential component of construction management. It evolves to highlight effective forms of project management in ensuring the high profits in construction businesses. However, there is no comprehensive assessment of the adoption and significance of digital technology (DT) that has been shown to be helpful in the organisation management. As a result, the lack of a reliable source that can establish the significance of a construction firm, the extent of technology application as competitive advantage is also uncertain. This restricts direct interaction between the parties involved in the project management. Therefore, digital technology capability (DTC) is not disclosed the level of utilisation and importance in project management that influence organisation in driving organization innovation for future investment. To fill the gap, this paper aimed to identify the key elements, to map the state and interpret the available evidence through resource-based view (RBV) theory of DT utilize according to firm requirement related to procurement, logistics, construction and marketing. The results of four elements which twenty-five DTC were interpreted into quantitative questionnaire by using dual Likert-scale and 341 out of 363 participants are gathered. It has been tested for validity and reliability using ranking and Important-Performance analysis (IPA) approach. The study found that the majority of participant have vigorous in connectivity, intermediate in digital access and emerging technology but shallow in automation technology. Therefore, it provides a current picture to government, practitioner, leader and subordinate in the organization to optimize DTC that is often used and effective to all management parties involved in the firm. In fact, this is able to set an organization innovation strategy in the digital age.

1. Introduction

The construction industry is regarded as a complex yet crucial business on a global scale. According to Wang *et al*., [1], within three years, the global construction market will reach the record level of 15 trillion dollars and will continue to grow at a yearly rate of around 3% through to 2025.

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One of the key industries in Malaysia is construction, which is estimated to provide over 1.38 million jobs, account for 10% of all employment, and be worth over RM 27.7 billion [2]. The essential requirement for digitalization is apparent, providing important benefits to assist intricate industries. For instance, digital technology (DT) is taking place in the fields of finance, manufacturing, banking, and health care [3] at a much slower pace in construction [4]. An area where digitalization has made significant progress in the construction industry is the improved use of emerging technology [5], automation [6], connectivity [7] and digital access [8]. The current corpus of information claims that the construction industry's fragmentation prevents it from undergoing a more streamlined digital transition than other industries [9]. The introduction of increasingly cutting-edge technologies like robotics and automated task signals the expansion of digitalization beyond routine daily tasks [10]. This evolution is improving competence by reducing the margin of task errors through the capacity to learn and identify patterns [11]. According to Alsunaidi *et al*., [7-9] it is necessary to concentrate on technical issues when examining digital manifestation in construction organisations. This is evidenced by [12], who document the vital improvements in performance, economy, and sustainability brought about by digital transformation in the digital age.

Mutual digital mindset and skillset by business leaders and managers have a significant impact on their organization's ability to embrace digital transformation [8,21,28]. Hence, construction companies need to put awareness of Industry Revolution 4.0 at the forefront of their digitization efforts by the deployment of DT capability has influenced organization productivity and constant innovation [20]. However, it is believed that in order for practice and academia to reflect various viewpoints, a bridge is required. It is believed that such an approach will reveal DT from an internal perspective as opposed to what the literature identifies externally at top management levels. Only a few studies have been done that specifically address the role of DT play in fostering innovation in the construction industry [8,13,14,16] but not the performance of digital technology capability (DTC) in the construction management life-cycle.

In contrast to other industries, the construction has few studies on DTC. The research body focuses mostly on education [17], health care [18] and governmental institutions [20]. However, there are very few studies that specifically address DTC that are applicable in procurements, logistics, construction, and marketing in the construction business [15]. The slow rate of digital transformation in the construction industry calls for filling this knowledge gap and directing more research in a direction that is deemed essential. This will also provide the evidence needed to make wise decisions about how to overcome the barriers that stand in the way of an effective organization. As a result, this paper makes a significant contribution to filling the research gap. The performance and importance of DT enactment in the construction business are thus explored in this study.

1.1 Current Construction Digital Technology Capabilities

Conventional digital and mutual digital has a significance different in terms in managing as the concept of emergence of the latest technology through practical construction to produce faster, safer and effective decision-making [20]. For instance, cloud- based storage (mutual digital) are more effective rather than server storage (conventional digital) where a risk of data loss due to damage or main server shutdown due to lightning or short-circuit [5]. Current technological trends such as Macro-BIM, 3D BIM, cost modelling and construction schedule with 5D, Pre-fabrication or Modular construction, power saving building systems, smart buildings, robotic automation and 3D printing help leader and subordinate in construction management life-cycle interaction between all organization parties [13,27,28].

An effective managerial paradigm for identifying the strategic DT capability that an organization might leverage to gain a sustained competitive edge is the resource-based view (RBV) [19] where promotes tangible and intangible DT resources as an enabler of organization innovation to improve leader and subordinate' skills to do a daily task that is more complex and difficult to perform by help out from automated in accelerating management [23]. However, as diverse tactics provide varied results, how an organization responds to digitalization determines how DT is implemented [24]. Among the important stakeholders in the construction industry, there is a rising need to investigate the existing state of obtaining suitable DT. When detecting this digitalization at various stages and recording related information, literature of DT capability in sourcing, acquiring, paying for goods and services [25], planning, controlling transportation, workers and resources [26], execution on construction site [27] and promoting good or services to the client [28] can be known deeply through. The body of knowledge is currently available, however, lacks a sufficient understanding of alternative perspectives that could support research initiatives to detail the pertinent DT as required by the organization culture and economy by guiding them towards the crucial pressure points for an effective transformation. Thus, Table 1 show construction DTC make up the indicated of four elements that are related in the construction life-cycle phase.

Table 1
Identification of research construct

Element of DTC Practices	[1]	[5]	[8]	[9]	[12]	[13]	[23]	[28]	[29]	[32]	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]	[39]	[48]
Emerging Technology																				
Productivity Software	●	●		●		●		●					●			●	●			●
Risk Analysis Software	●								●			●		●	●					
Internet of Thing				●	●				●	●				●						●
Artificial Intelligence		●			●				●			●	●		●		●			
Block Chain		●		●	●			●				●	●	●		●				
Digital Automation																				
Robotic Process					●					●				●	●	●	●	●		●
Additive Manufacturing	●	●		●				●					●			●	●			
AR, VR, Mixed Reality				●		●							●			●				●
Drone Technology	●		●					●	●			●	●		●					
Industrial Building System, IBS	●	●			●		●				●				●		●	●		
Connectivity																				
Data Collection Apps			●		●		●				●	●	●	●	●			●		
Near Real-Time System			●				●	●	●											
Digital Sensor	●	●			●	●	●	●			●		●			●				
Messaging	●	●				●	●	●			●							●		
Block Chain						●						●	●						●	
Cloud Storage					●	●	●				●		●				●	●		
Big Data				●	●				●	●				●						●
Digital Access																				
Integration Software			●	●	●					●					●	●		●	●	
Scheduling Software			●				●	●	●											
Estimation Software	●	●			●	●	●	●			●		●			●				
3D Modelling up to 7D	●	●					●	●			●							●		
Collision Detection Software						●						●	●						●	
Teleconferencing					●	●	●				●		●				●	●		
SaaS Construction	●				●				●	●	●						●	●		
Real-Time Information		●		●	●	●	●							●	●			●		

*****AR (Augmented Reality), VR (Virtual Reality), SaaS (Software as A Service, BIM (Building Information Modelling)

The term “digitalisation” refers to connecting people, devices, and data with DT to enhance and alter business processes [29], but the phrase "digital transformation" is rife with misinformation [21]. Initially, the term seems to emphasize a fundamental change in how firms approach their work and respond to digital trends in a cutthroat market [40]. To assist managers, navigate the digital adolescence, conceptualizing digitalization should be viewed as a continual process for growth and development. Furthermore, the move to digitalization in small-medium enterprise, SMEs from a legacy perspective and increased corporate integration of IT and organization innovation in the new era of business information technology (IT) emphasis the need for digital proficiency [30]. Due to its impact on internal orientation and an organization's business strategy, putting such capability at the centre of this inquiry and influencing how businesses approach their respective markets [32,33].

DTC is able to make the construction process on the project development more secure and efficient, resulting in an increase in productivity among developer, contractor, consultant, suppliers and other parties involved in the project even less interaction in order to be able to achieve the main goal in a project [43], resulting the domino effects as collaboration form all parties in one digital platforms [31]. It also allows construction organization to handle more complex projects during limited time with the help of construction DT that can assists in the process of analysis, managing, documenting, video and call conferencing the project information deliver through virtual [5,36]. It is possible to claim that previous research should investigate digital transformation from a technology-oriented perspective [32]. However, there is not much study on utilizing DT in Malaysia's construction business. Therefore, the purpose of this study is to examine the potential state of DT and analyse the information that has been gathered on its implementation in the construction industry, gathering the perspectives of the important either a necessity or a willpower as development and addressing the research question (RQ): What is the current level of digitalisation in Malaysian construction industry?

2. Research Methodology

This study begins with literature review based on RBV theory to classified tangible and intangible DT resources in the construction firm as competitive advantages exploitation opportunities [45], where four elements of DTC namely; emerging, automation, connectivity and digital access as characteristics to acquire research construct related in project management with varied evaluation standards in literature analysis, as shown in Table 1.

A quantitative questionnaire survey is used to gather data, and participants are presented with dual Likert scale questions that respond five points to measure the importance (1 = strongly not important to 5 = strongly important) and performance (1 = strongly disagree to 5 = strongly agree). Without influencing their input in any way, this method effectively captured the experience and viewpoints of the participants. [38], assert that this method may be used to identify the current state of DT and understand the important of related DT enactment in the construction industry. This was appropriate for the current study, which sought employer and employee perspectives of their organisational culture towards digital innovation, particularly in construction DT that is vital in the digital era by reflecting their firm's efforts to bring about digital transformation.

A stratified random sampling approach is adopted to identify suitable participants from developer, consultant and contractor firm that be listed in Construction Industry Development Board (CIDB), Board of Engineers Malaysia (BEM), Board of Architects (BOA) and Board of Quantity Surveyors (BQSM) website where according to Department of Statistic Malaysia in 2022 there are 2,173,400 populations employed in the construction industry and 384 samples are considered saturated data according to Krejcie and Morgan (1970). Therefore, professionals from the construction industry who are easily accessible in terms of access, location, time, and willingness are

included in the research [47]. Such a sample type has been defined as the digitalization of the construction organization's ambassadors [48].

After the final data has been analysed through Pearson correlation analysis and factor analysis, the data is analysed using the Ranking Analysis (RA) and Important-Performance Analysis (IPA) described by [46] as an analytical strategy that is aligned with the research issue of this paper. There are two primary outputs from IPA to identify the performance indicator that will be used to rate the important of the qualities for the DT being surveyed [49]. For this purpose of research, indicator for 'performance' is classified as 'implementation' which the used of the DT. To distinguish between the two, implementation mean and performance mean being deducted to get a gap mean as to be plotted into IPA Grid. A two-dimensional IPA grid is divided into four quadrants with performance on the x-axis and importance on the y-axis. As a result of this, four quadrants namely *Concentrate Here, keep up the Good Work, Low Priority*, and *Possible Overkill* are created. The quadrants can be used to develop suggestions regarding the current status of DT by contrasting them [50].

3. Findings

The purpose of the study is to ascertain the level of DT adoption in the construction industry from both an employer and employee standpoint. From the survey found 363 participants are successful completing the questionnaire form. The analysed dual Likert scale responses using ranking and IPA approach, where DT elements are not influence by author and naturally come from repetitive patterns [9,11,20]. These items provide insights into participants' perspectives on the current role of DT in driving innovation in their companies. Twenty-five specific DT are presented in Table 5.

3.1 Samples Demography, Validity and Reliability Test

In order to gain a perspective from a utilisation perspective, participants must be employed in construction industry at the time they participate in this study. This sample has been determined to be important to reflect the DT discernment for digital development of existing technologists, bridging the employer-employee viewpoint with the organisation's stance. Information regarding the participants is visualised, such as percentage of operational definition of digitalization understanding, Figure 1(a) and percentage of participant that use DT in their scope of work, Figure 1(b). We acknowledge that the construction industry is not homogeneous, so our analysis examined the sample at an aggregate level rather than attributing some typologies to specific company sizes or scales. It may be argued, therefore, that representing smaller and less represented populations is a merit.

Figure 1(a) show 333 participants (92%) are recognising the digitalisation however 30 participants (8%) do not know. This shows there are a few participants are not sure the literal meaning of the term digitization, and even do not use technology as a project management platform in the organization. Meanwhile Figure 1(b) show 341 participant (94%) are implemented DT in their organisation as goals of this research whereas 22 participants (6%) did not, where considered invalid as the research samples. The participants do not have experience and rigid perspective in DT implementation and even make it difficult to interpreted the importance of the technology involved.

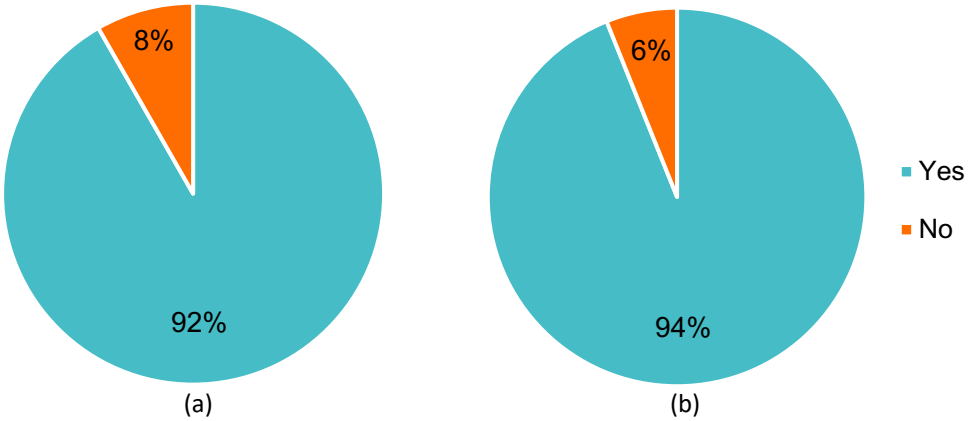

Fig. 1. (a) Operational definition of "digitalization" understanding (b) Utilized digital technology in daily work

Tables 2 summarize the results of validity and reliability tests for survey statement items from four elements of construction DT. Based on table, it was found that the validity test results for each item or dimension in the performance and importance aspects were found to have a correlation value greater than the R-table (0.254) while reliability test shows Cronbach's Alpha coefficient value is greater than 0.6. Thus, all statement items proposed in this research questionnaire are declared valid and reliable. Thus, 341 out of 363 samples are suitable and sufficient for achieving such saturation [51], relevant with 0.965 reliability statistics from Cronbach's Alpha based on standardisation item as shown in Table 6 and therefore are considered to apprise the study of participants perspectives of DT enactment in the construction industry.

Table 2
Validity and reliability test

Variables	No of items	Performance	Important	Validity test (Correlation)		Reliability test α (Alpha Cronbach's)	
				R-Table Value	Information	Standard Reliability	Information
Emerging Technology	5	0,887	0,899	0,254	Valid	0,6	Reliable
Automation	5	0,864	0,826	0,254	Valid	0,6	Reliable
Connectivity	7	0,939	0,893	0,254	Valid	0,6	Reliable
Digital Access	8	0,927	0,968	0,254	Valid	0,6	Reliable

The statistical information gathered about the respondent's position in the construction organisation is displayed in Table 3. The respondent's background was categorised into four subjects, including occupation, field of work, respondent role and experience. The result showed that 16.42% work in developer, 21.11% work in consultant, 39.88% work in enterprise of the construction sector, 7.04% as local authority, 4.11% as suppliers and 11.43% in programmer, freelance and professionals. Three level of management is being classified which is program manager, project manager and construction manager to get personal opinions in stages according to the scope of work and responsibilities held where there are differences from the aspects of DT used. As far as respondent industry is concerned, most of them 55.42% supervisory management and 25.22% top management as highest participant compared to frontline management 19.35%. The participants have more than five years of experience in Malaysia's construction sector only 9.38% while less than three years of experience is 39.58%.

Table 3
Demographics of participants

Category of Company	Frequency	Percentage (%)
Developer	56	16.42
Consultant	72	21.11
Contractor (Big /Small-Medium Enterprise)	136	39.88
Local Authority	24	7.04
Suppliers	14	4.11
Others	39	11.43
Management Position	Frequency	Percentage (%)
Program Manager	86	25.22
Project Manager	189	55.42
Construction Manager	66	19.35
Years of Experience	Frequency	Percentage (%)
Less than 3 years	135	39.58
3 to 5 years	80	23.46
6 to 10 years	64	18.76
11 to 15 years	30	8.79
More than 15 years	32	9.38

3.2 Ranking Analysis

Table 4 shows the top twelve most implemented and crucial DT in procurement, logistics, construction and marketing phase in construction life-cycle management. The level of performance will indicate the state of DT as commonly utilised in construction industry.

Table 4
Top 12 of digital technology implemented and crucial in construction industry

Code	Digital Technology	Level of Performance		Level of Importance	
		Mean	Rank	Mean	Rank
D8	Real-Time Information	4.35	1	4.34	1
C6	Cloud Storage	4.30	2	4.31	2
D6	Teleconferencing	4.27	3	4.27	3
C4	Closed source software	4.24	4	4.24	5
C7	Messaging	4.15	5	4.24	4
C2	Near Real-time system	4.01	6	4.20	6
E3	Internet of Thing	3.90	7	4.01	9
C3	Digital Sensor	3.86	8	4.04	7
D2	Scheduling Software	3.77	9	3.93	13
A4	Drone	3.73	10	4.03	8
C5	Block Chain as e-payment	3.71	11	3.95	11
E2	Analytic Software	3.69	12	3.99	10

The table shows real-time information with 87% of participants agreed it being utilised and significantly important in their life-cycle management such e-payment and marketing. The second higher is cloud storage, 86% of participants applied *Dropbox, Google Drive* and *One Drive* as cloud-based storage in their organization. The third and fifth higher is teleconferencing and messaging with 85.4% and 83% the participants made use of digital communication as platform to interconnect with all parties involves in organization whereas fourth and sixth participants agreed to relied on closed source software, 84.8% with help of real-time system 80.2% makes it easy to work remotely without

limits. IoT such as *e-Supplier, e-Tendering* and *e-Housing* were attempted by 78% of participant in tracking purchasing the materials, getting tenderer from government and promote house revenue generators for certain region. Besides that, 77.2% participant chosen digital sensors such a smart supply-chain management, fire-detection sensor in office and site as connected sensor and actuators to manage and monitor the environment. Schedule Software is significantly used by 75.4% participant to allocate project schedule through *Microsoft Project* and *Oracle Primavera* to planning and tracking of time spending. In addition, drones were used by 74.6% of respondents for tasks such as site analysis, planning, design, project reporting and services marketing. The eleventh place is blocking chain as online payment that being used 74.2% of participant while analytic software an instance *Procore* and *Autodesk Construction Cloud*, 73.8% participants utilise to identifying patterns, trends and linkage in existing data.

3.3 Important-Performance Analysis (IPA)

The intersection in the IPA grid is made available using the mean level of important at 3.54 and the mean level of performance at 3.92 as shown in Table 5. Therefore, the importance and performance can be plotted on the IPA grid, construction firms in organization would be able to quickly identify areas in which DT should allocate their resources to strategize and maximise a high return of investment for the future. The IPA grid is divided into four main quadrants; Quadrant I: *Concentrate Here*, Quadrant II: *Keep Up the Good Work*, Quadrant III: *Low Priority* and Quadrant IV: *Possible Overkill*. The details of each digitalization and their respective quadrant are as shown in Figure 2.

Table 5
Twenty-five digital technology related in construction industry life-cycle management

Code	Digital Technology	Level of Implementation		Level of Importance	
		Mean	Rank	Mean	Rank
E1	PlantGrid, Kahua, RedTeam	3.52	13	3.94	12
E2	Procore, Autodesk Construction Cloud, BIM	3.69	12	3.99	10
E3	Just-In-Time, E-supplier	3.90	7	4.01	9
E4	Novade, Speedbrick	3.31	19	3.73	19
E5	Smart Contract, Ethereum, Hyperledger	3.20	22	3.77	17
A1	Excavation Robots, Bricks Robots	2.75	25	3.40	24
A2	3D model house, 3D Printing	2.82	24	3.34	25
A3	Storyboard VR, Arki, Smart Reality	3.40	16	3.76	18
A4	Drone Technology, UAV, 3D Mapping	3.73	10	4.03	8
A5	Pre-Fabrication, Modular Construction	3.12	23	3.69	21
C1	E-suppliers, Marketing apps	3.36	18	3.91	14
C2	Microsoft 365, Goggle sheet/ docs/ finance	4.01	6	4.20	6
C3	LiDAR, RFID tag, IoT sensor	3.86	8	4.04	7
C4	Messages by Google, iMessage, Skype, Outlook	4.24	4	4.24	5
C5	Labour market, ease payment, logistics	3.71	11	3.95	11
C6	Dropbox, Google Drive, One Drive	4.30	2	4.31	2
C7	Google Cloud BigQuery, Microsoft SQL Server, Snowflake	4.15	5	4.24	4
D1	BIMsync, Autodexk Construction Cloud	3.50	15	3.80	16
D2	Microsoft Project, Primavera	3.77	9	3.93	13
D3	Cubicost, Buildxact, Redteam	3.38	17	3.68	22
D4	BIM, Revit, Cubicost TAS & TRB	3.30	20	3.91	15
D5	BIM Clash Detection	3.25	21	3.61	23

D6	Google Meet, Webex Meetings, Zoom, Microsoft Team, Whereby	4.27	3	4.27	3
D7	Novade, Dropbox	3.50	14	3.71	20
D8	Social media, e-payment, marketing	4.35	1	4.34	1
	Average/ Total	3.92	25	3.54	25

In quadrant I, *Concentrate Here*, participant perceive the attributes as very important, but the perspectives of performance levels are below average. Thus, further improvement efforts should be concentrated here. There are two attributes that fall into this quadrant which were productivity software (E1) and data collection apps (C1).

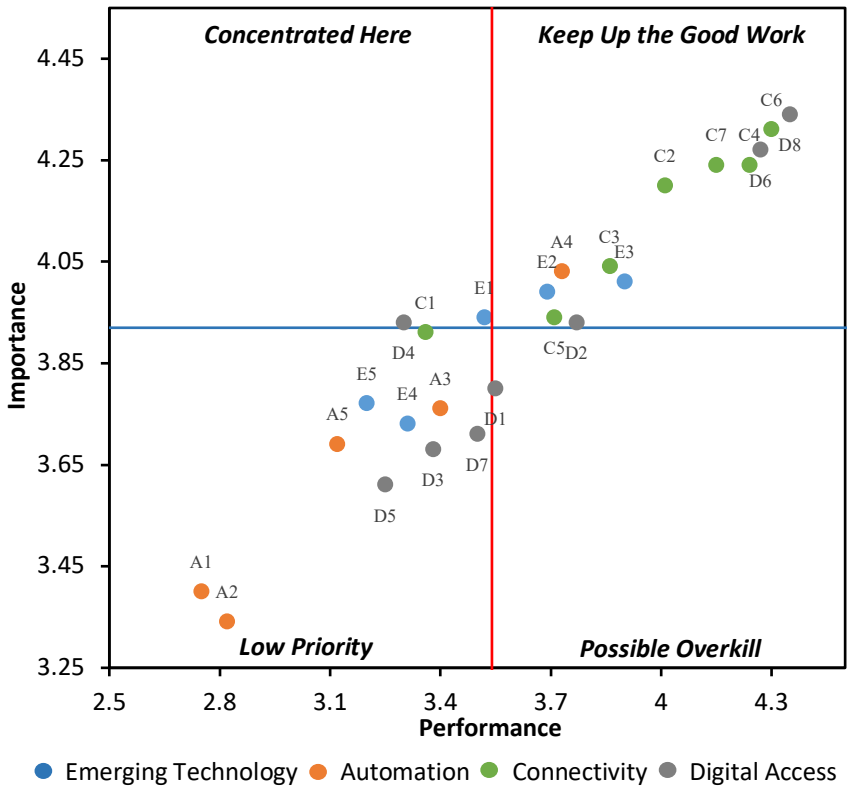

Fig. 2. IPA grid for digitalization in Malaysian construction industry

Another important finding was that twelves DT such as real-time information (D8), cloud storage (C6), teleconferencing (D6), closed source software (C4), messaging (C7), real-time system (C2), IoT (E3), digital sensor (C3), scheduling software (D2), drone (A4), block chain (C5) and analytic software (E2) situated in quadrant II, *Keep Up the Good Work*, are perceived to be very important and utilised from the participant's perspective. This DT contributes to the success of the projects and construction organization parties involves should keep up the good work in maintaining or delighting their firms, as otherwise, these benefits might risk falling into the *Concentrate Here* quadrant. Figure below show the IPA grid for the current level of digitalisation in terms of performance and importance of DT in Malaysian construction industry.

Some of the DT that are literally categorised as *Low Priority* in quadrant III are software as a service (D7), augmented reality, virtual reality, mixed reality (A3), estimation software (D3), artificial intelligence (E4), 3D modelling (D4), collision detection (D5), block chain (E5), pre-fabrication, modular construction (A5), addictive manufacturing (A2), robotic process (A1). The participant scored

poorly in this quadrant for both significance and performance, which caused the firm to pay less attention to invest by leaders.

In the quadrant IV, referred to as *Possible Overkill*, there is one DT, namely: integration through AI or software (D1). Here the participant is very satisfied with the current performance but the important of the DT are perceived as not really important. This gives the impression that (D1) is less effective for management organizations because it still requires manual engagement from subordinate. Therefore, the construction firm should consider allocating their resources, such funds, time and effort, elsewhere, especially on those DT in the *Concentrated Here* quadrant.

4. Discussion

While the main finding is to map the state of DT as mention in Figure 2, the level of performance will indicate the current implementation of DT as commonly utilised in construction industry while the level of important will indicate the potential of DT as return of investment for future organization innovation opportunities in construction industry. As a result, differences in importance and performance evaluations can have detrimental effects; it shows that even when an item's value is taken into account, its performance is still potentially problematic [38]. Majority of participants show strong interest in connectivity elements such as real-time information (D8), cloud storage (C6), teleconferencing (D6), closed source software (C4), messaging (C7), real-time system (C2), IoT (E3), digital sensor (C3), scheduling software (D2), drone (A4), block chain (C5) and analytic software (E2) have relative advantage to increase market coverage, productivity, profitability, and cut costs since it is simple to utilize and just takes rudimentary knowledge. Meanwhile, top management and managers as a diver of the decision-making stage easy to make decisions with the help of this technology and even help convey information quickly to subordinate. Table 6 represents the hierarchy of current level of digitalization in Malaysian construction industry.

Table 6
Ranking of digital technology element based on dual-ranking analysis

Rank	DT Elements	Number of items	Cronbach's a value
1	Connectivity	7	*0.916*
2	Digital access	8	0.905
3	Emerging Technology	5	*0.898*
4	Automation	5	*0.845*
	Total	25	*0.965*

Participants show medium interest in digital access and emerging technologies such as existence software as a service (D7), augmented reality, virtual reality, mixed reality (A3), estimation software (D3), artificial intelligence (E4), 3D modelling (D4), collision detection (D5), block chain (E5), Pre-fabrication, Modular construction (A5), addictive manufacturing (A2), robotic process (A1) are lower demanding in Malaysia construction industry while minimal enthusiasm in automation, such addictive manufacturing (A2) and robotic processes (A1) where requires large capital and has limited interest in small or medium projects [10,11]. Robotic programs, artificial intelligence (AI), and 3D printing require specialized digital skill expertise to be applied in the construction stage, which aids the contractor and project manager in logistics, preliminary work, project design, site supervision, and marketing while also integrating and collaborating with other parties to speed up the construction process [12]. Furthermore, integrating by AI or software (D1) is a digital service that requires integration with third parties, where there is no interest in small-scale projects with very

little profit. Most of the DT in quadrant III and IV is equivalent and relevant for large companies because of the complexity of projects management and large margins are required such as mega projects with a longer duration. It would be possible to close other research gaps through the formulation of improved strategies, especially for the areas in a quadrant where the majority of participant is concentrated [39]. As a result, it can refer to and motivate construction firms to invest in DT as a long-term benefit in order to overcome some relevant project challenges [43-47].

This research study was able to offer helpful suggestions for future digital strategy development for construction companies and associated stakeholders. The IPA grid reveals areas of strategic focus, i.e., Low Priority quadrants with findings in this area that require the greatest attention. As part of this paper, it is important to note that the construction industry members are clearly working full-time and only participants who have used DT were asked to complete the survey in order to identify those who judge the importance and performance of each DT elements. The general population probably holds a different perspective on the significance and effectiveness of the construct mentioned above however, cannot be denied these studies demonstrate construction firms should consider automation technologies as demanded in their project management [16] as a remote future in productivity goal.

5. Conclusion and Recommendations

The study aimed to identify the key elements, to map the state and interpret the available evidence of DT enactment in the construction industry. There are several studies on DT in different study areas and regions, but there is lack of studies that specifically address the Malaysian construction industry. Therefore, this study has a timely impact, and can be seen as a clear call for researchers studying the adoption of innovation to focus on the technical aspects associated with a successful digitalization.

The literature research of twenty-five DT enactment can be grouped under four key elements: emerging technology, automation, connectivity and digital access. Resulting from domino effects among developer, contractor, consultant, suppliers and other parties involved, DT capability were able to make the construction firm business development more secure and efficient, resulting in an increase in productivity in the project even less interaction in order to be able to achieve the main goal in a project as collaboration in one digital platforms. Digital transformation is already occurred on connectivity, emerging and digital access is still in the digitalization while automation is still digitizing phase. The main finding, Malaysia construction industry is characteristically slow at adopting advance DTC, yet not realize the significant of utilize its considered vital to accelerating digitalisation in their business. DT capability with high opportunities that involving for future maturing such software as a service (D7), augmented reality, virtual reality, mixed reality (A3), estimation software (D3), artificial intelligence (E4), 3D modelling (D4), collision detection (D5), block chain (E5), pre-fabrication, modular construction (A5), addictive manufacturing (A2), robotic process (A1) needs to be exposed from now on. Therefore, it gives practitioner, leader and subordinate in the organisation an overview that they can optimise widely used and efficient DT for all management parties operating in the organisation. In digital era, this may be used to establish a corporate organization innovation plan as strategies and bring towards construction industry ecosystem. For instance, the management of the organization in a firm needs to collaborate with the developer (client), government, sub-contractor, supplier and consultant managers through virtual integration technology which directly impact on the time, cost and quality in construction life-cycle management.

Initiatives from the government are always crucial to advancing DT in firm organization. Thus, in order to encourage the use of DTC in the construction industry, this study also recommends

alterations or revisions to the government's current digital policy and strategy. Since computer gear and software are the foundation of the DTC application, the Malaysian government ought to guarantee its accessibility at a reduced expense. For instance, lower taxes or no taxes at all on imported modular building supplies. Additionally, the authority might provide software frameworks greater incentives to produce software that works well at a lesser cost. More graduates now have the option to enrol in courses focused on construction digital management thanks to the government's emphasis on technical education. In this regard, the government must create a thorough strategy that includes incentive, training, and support programmes, as well as suitable and integrated DTC usage programmes. In conclusion, this research suggests that management of SMEs, large corporations and the government should pay attention to the internal and external elements that lead to the effective implementation of DTC and support national economic growth.

The results of this study may not be properly interpreted due to two limitations. First, methodological limitations where only conducted within the scope of construction firm in Malaysia and only studied several DTC that only affect the partial management of construction firms especially in procurement, logistics, construction and marketing and therefore, may not represent views of the related DT overall construction phase such as preliminary and post-construction phase. Second, data collection and analysis where participants have limited choice in response may lead to broad information and reference to see the level of competition for construction firm in Malaysia. Given that this was a preliminary study, there is need for more research on DTC, particularly in the construction industry. The results of this study can be used to inform the design of a qualitative study to gather opinions from a predetermined sample size and assess the significance of the influences of various variables found. Separate studies could also be conducted with a focus on each construct, particularly the automation element, to provide an in-depth awareness of the interest to adopt DT in the construction industry in improving the productivity of project management. Apart from that, future researchers can look at other points of view in looking at small-medium enterprise, SMEs and multi-national corporations, MNCs comparison, so that they can enrich studies for future research.

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References

[1] Wang, Kaiyang, Fangyu Guo, Cheng Zhang, and Dirk Schaefer. "From Industry 4.0 to Construction 4.0: Barriers to the digital transformation of engineering and construction sectors." *Engineering, Construction and Architectural Management*, (2022). https://doi.org/10.1108/ECAM-05-2022-0383

[2] Najib, Iskandar Zulkarnain Mohd, Rumaizah Mohd Nordin, Ezlina Mohd Ahnuar, and Khalida Mohd Sukor. "Malaysian as the component of labour force for construction industry in Malaysia." In *MATEC Web of Conferences*, vol. 266, p. 01007. EDP Sciences (2019). https://doi.org/10.1051/matecconf/201926601007

[3] Hossain, Md Aslam, and Abid Nadeem. "Towards digitizing the construction industry: State of the art of construction 4.0." In *Proceedings of the ISEC*, vol. 10, pp. 1-6. (2019). https://doi.org/10.14455/ISEC.res.2019.184

[4] Srivastava, Yogesh Chandra, Abhishek Srivastava, and Consuelo Granata. "Digitally Enabled Organizations-Leveraging New Age Technologies," (2021) https://doi.org/10.2118/207380-MS

[5] Smartsheet Inc. "5 Emerging Trends in the Construction Industry," (2018).

[6] Bello, Sururah A., Lukumon O. Oyedele, Olugbenga O. Akinade, Muhammad Bilal, Juan Manuel Davila Delgado, Lukman A. Akanbi, Anuoluwapo O. Ajayi, and Hakeem A. Owolabi. "Cloud computing in construction industry: Use cases, benefits and challenges." *Automation in Construction* 122 (2021): 103441. https://doi.org/10.1016/j.autcon.2020.103441

[7] Alsunaidi, Shikah J., Abdullah M. Almuhaideb, Nehad M. Ibrahim, Fatema S. Shaikh, Kawther S. Alqudaihi, Fahd A. Alhaidari, Irfan Ullah Khan, Nida Aslam, and Mohammed S. Alshahrani. "Applications of big data analytics to control COVID-19 pandemic." *Sensors* 21, no. 7 (2021): 2282. https://doi.org/10.3390/s21072282

[8] Ekechukwu, John, and Thorsten Lammers. "Digital Technology to Enhance Project Leadership Practice: The Case of Civil Construction." *Digital Transformation in Business and Society: Theory and Cases* (2020): 247-271. https://doi.org/10.1007/978-3-030-08277-2_15

[9] Aripin, Irrma Diana Mohd, Emma Marinie Ahmad Zawawi, and Zulhabri Ismail. "Factors influencing the implementation of technologies behind industry 4.0 in the Malaysian construction industry." In *MATEC Web of Conferences*, vol. 266, p. 01006. EDP Sciences, 2019. https://doi.org/10.1051/matecconf/201926601006

[10] Magnenat, Stéphane, Roland Philippsen, and Francesco Mondada. "Autonomous construction using scarce resources in unknown environments: Ingredients for an intelligent robotic interaction with the physical world." *Autonomous robots* 33 (2012): 467-485. https://doi.org/10.1007/s10514-012-9296-x

[11] Martinez, Santiago, Juan Miguel Garcia-Haro, Juan G. Victores, Alberto Jardon, and Carlos Balaguer. "Experimental robot model adjustments based on force–torque sensor information." *Sensors* 18, no. 3 (2018). https://doi.org/10.3390/s18030836

[12] Aghimien, Douglas, Clinton Aigbavboa, Ayodeji Emmanuel Oke, and John Aliu. "Delineating the people-related features required for construction digitalisation." *Construction Innovation* (2022). https://doi.org/10.1108/CI-01-2022-0012

[13] Ismail, Asnidatul Adilah, and Razali Hassan. "Technical competencies in digital technology towards industrial revolution 4.0." *Journal of Technical Education and Training* 11, no. 3 (2019). https://doi.org/10.30880/jtet.2019.11.03.008

[14] Dehdasht, Gholamreza, M. Salim Ferwati, Nazirah Zainul Abidin, and Michael Olubukola Oyedeji. "Trends of construction industry in Malaysia and its emerging challenges." *Journal of Financial Management of Property and Construction* 27, no. 2 (2022): 161-178. https://doi.org/10.1108/JFMPC-08-2020-0054

[15] Johari, Muhamad Shafiq, and Syamsul Hendra Mahmud. "Digital Transformation is the New Norms in Construction Industry." In *International Conference on Trends in Advanced Research*, vol. 1, pp. 384-391. 2023.

[16] R. Berger and K.-S. Schober, "Artificial intelligence in the construction industry.," (2021).

[17] Hapha, Yingsan, and Kanokorn Somprach. "A study of digital leadership and creative leadership that affect innovation in Thai higher education." *Journal of Critical Reviews* 6, no. 4 (2019): 37-41.

[18] Martins, Henrique. "Digital transformation and digital leadership." *Healthcare informatics research* 25, no. 4 (2019): 350-351. https://doi.org/10.4258/hir.2019.25.4.350

[19] Barney, Jay, Mike Wright, and David J. Ketchen Jr. "The resource-based view of the firm: Ten years after 1991." *Journal of management* 27, no. 6 (2001): 625-641. https://doi.org/10.1177/014920630102700601

[20] Chen, Xichen, Alice Yan Chang-Richards, Antony Pelosi, Yaodong Jia, Xuesong Shen, Mohsin K. Siddiqui, and Nan Yang. "Implementation of technologies in the construction industry: a systematic review." *Engineering, Construction and Architectural Management* 29, no. 8 (2022): 3181-3209. https://doi.org/10.1108/ECAM-02-2021-0172

[21] Schwarzmüller, Tanja, Prisca Brosi, Denis Duman, and Isabell M. Welpe. "How does the digital transformation affect organizations? Key themes of change in work design and leadership." *Management Revue* 29, no. 2 (2018): 114-138. https://doi.org/10.5771/0935-9915-2018-2-114

[22] Perera, S., S. Nanayakkara, and T. Weerasuriya. "Blockchain: The next stage of digital procurement in construction." *Academia Letters* 10 (2021). https://doi.org/10.20935/AL119

[23] Magnenat, Stéphane, Roland Philippsen, and Francesco Mondada. "Autonomous construction using scarce resources in unknown environments: Ingredients for an intelligent robotic interaction with the physical world." *Autonomous robots* 33 (2012): 467-485. https://doi.org/10.1007/s10514-012-9296-x

[24] Lim, Yaik-Wah, Philip CH Ling, Cher Siang Tan, Heap-Yih Chong, and Ashwin Thurairajah. "Planning and coordination of modular construction." *Automation in Construction* 141 (2022): 104455. https://doi.org/10.1016/j.autcon.2022.104455

[25] Petrov, Pavel, Mihail Radev, Georgi Dimitrov, Adrian Pasat, and Alexander Buevich. "A systematic design approach in building digitalization services supporting infrastructure." (2021): 31-34. https://doi.org/10.18421/TEM101-04

[26] Morgan, Bethan. "Organizing for digitalization through mutual constitution: the case of a design firm." *Construction management and economics* 37, no. 7 (2019): 400-417. https://doi.org/10.1080/01446193.2018.1538560

[27] Parusheva, Silviya. "Digitalization and Digital Transformation in Construction-Benefits and Challenges." *Information and Communication Technologies in Business and Education* (2019): 126-134.

[28] Phelps, Kirstin C. ""So much technology, so little talent"? Skills for harnessing technology for leadership outcomes." *Journal of Leadership Studies* 8, no. 2 (2014): 51-56. https://doi.org/10.1002/jls.21331

[29] Aghimien, Douglas, Clinton Aigbavboa, Ayodeji Oke, and Nteboheng Koloko. "Digitalisation in construction industry: Construction professionals perspective." In *Proceedings of the Fourth Australasia and South-East Asia Structural Engineering and Construction Conference, Brisbane, Australia*, pp. 3-5. (2018). https://doi.org/10.14455/ISEC.res.2018.90

[30] Warner, Karl SR, and Maximilian Wäger. "Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal." *Long range planning* 52, no. 3 (2019): 326-349. https://doi.org/10.1016/j.lrp.2018.12.001

[31] Shahadat, MM Hussain, Md Nekmahmud, Pejman Ebrahimi, and Maria Fekete-Farkas. "Digital Technology Adoption in SMEs: What Technological, Environmental and Organizational Factors Influence in Emerging Countries?", *Global Business Review* (2023). https://doi.org/10.1177/09721509221137199

[32] Teece, David J. "Business models and dynamic capabilities." *Long range planning* 51, no. 1 (2018): 40-49. https://doi.org/10.1016/j.lrp.2017.06.007

[33] Čirjevskis, Andrejs. "The role of dynamic capabilities as drivers of business model innovation in mergers and acquisitions of technology-advanced firms." *Journal of Open Innovation: Technology, Market, and Complexity* 5, no. 1 (2019): 12. https://doi.org/10.3390/joitmc5010012

[34] Buisman, Ad. "How are engineering and construction companies adapting digital to their businesses." *Ernst&Young: London, UK* (2018).

[35] Simonsson, Johan, and Mats Magnusson. "Collaboration challenges in digital service innovation projects." *International Journal of Automation Technology* 12, no. 4 (2018): 499-506. https://doi.org/10.20965/ijat.2018.p0499

[36] Hossain, Md Aslam, and Abid Nadeem. "Towards digitizing the construction industry: State of the art of construction 4.0." In *Proceedings of the ISEC*, vol. 10, pp. 1-6, (2019). https://doi.org/10.14455/ISEC.res.2019.184

[37] Zulu, Sambo Lyson, and Ali M. Saad. "A Sensemaking Perspective of Digitalisation in Construction Organisations." *Sustainability* 15, no. 3 (2023): 2344. https://doi.org/10.3390/su15032344

[38] Abalo, Javier, Jesús Varela, and Vicente Manzano. "Importance values for Importance–Performance Analysis: A formula for spreading out values derived from preference rankings." *Journal of Business Research* 60, no. 2 (2007): 115-121. https://doi.org/10.1016/j.jbusres.2006.10.009

[39] Apuke, Oberiri Destiny. "Quantitative research methods: A synopsis approach." *Kuwait Chapter of Arabian Journal of Business and Management Review* 33, no. 5471 (2017): 1-8.

[40] Jacobsson, Mattias, and Henrik CJ Linderoth. "Newly graduated students' role as ambassadors for digitalisation in construction firms." *Construction Management and Economics* 39, no. 9 (2021): 759-772. https://doi.org/10.1080/01446193.2021.1955398

[41] Bajpai, Avirag, and Subhas Chandra Misra. "Assessment of success determinants for implementing digitalization in Indian construction industry." In *2020 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, pp. 1-6, (2020). https://doi.org/10.1109/ICE/ITMC49519.2020.9198636

[42] Aghimien, Douglas Omoregie, Clinton Ohis Aigbavboa, and Ayodeji Emmanuel Oke. "Critical success factors for digital partnering of construction organisations–a Delphi study." *Engineering, Construction and Architectural Management* 27, no. 10 (2020): 3171-3188. https://doi.org/10.1108/ECAM-11-2019-0602

[43] Shirokova, Svetlana, Leonid Solovyov, Elizaveta Gnatenko, and Nadia Lohyeeta. "Implementation of the digital transformation concept during decision-making process in a construction company: Digital transformation as a driver of strategic decision-making in a commercial organization." In *Proceedings of the International Scientific Conference-Digital Transformation on Manufacturing, Infrastructure and Service*, pp. 1-8. 2020. https://doi.org/10.1145/3446434.3446464

[44] Abbu, Haroon, Paul Mugge, Gerhard Gudergan, and Alexander Kwiatkowski. "Digital leadership-character and competency differentiates digitally mature organizations." In *2020 IEEE international conference on engineering, technology and innovation (ICE/ITMC)*, pp. 1-9. IEEE, 2020. https://doi.org/10.1109/ICE/ITMC49519.2020.9198576

[45] Tereshko, Ekaterina, and Irina Rudskaya. "A Systematic Approach to the Management of a Construction Complex under the Conditions of Digitalization." *International Journal of Technology* 12, no. 7 (2021): 1437-1447. https://doi.org/10.14716/ijtech.v12i7.5356

[46] Gudergan, Gerhard, Paul Mugge, Alexander Kwiatkowski, Haroon Abbu, Gerrit Hoeborn, and Ruben Conrad. "Digital Leadership-Which leadership dimensions contribute to digital transformation success?", *IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, pp. 1-8. IEEE, (2021). https://doi.org/10.1109/ICE/ITMC52061.2021.9570231

[47] Sinenko, Sergey, Tatiana Poznakhirko, and Amir Tomov. "Digital transformation of the organization of construction production." In *E3S Web of Conferences*, vol. 258, p. 09020. EDP Sciences, (2021). https://doi.org/10.1051/e3sconf/202125809020

[48] Levenburg, Nancy M., and Simha R. Magal. "Applying importance-performance analysis to evaluate e-business strategies among small firms." *E-Service* 3, no. 3 (2004): 29-48. https://doi.org/10.1353/esj.2005.0012

[49] Konečný, Vladimír, Róbert Berežný, Mária Kostolná, and Pavel Šaradín. "Comparative Analysis of the Importance of the Requirements of Passengers and Evaluating the Quality of Air and Bus Transport." In *MATEC Web of Conferences*, vol. 236, p. 02006. EDP Sciences, (2018). https://doi.org/10.1051/matecconf/201823602006

[50] Apuke, Oberiri Destiny. "Quantitative research methods: A synopsis approach." *Kuwait Chapter of Arabian Journal of Business and Management Review* 33, no. 5471 (2017): 1-8. https://doi.org/10.12816/0040336