Factors influencing adoption of construction technologies in Vietnam's residential construction projects

Momade, Mohammed Hamza; Durdyev, Serdar; Tam, Nguyen Van; Shahid, Shamsuddin ; Mbachu, Jasper I C; Momade, Yusra

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Abstract

Purpose: Vietnam's Construction Technology (CT) adoption is low when compared to other countries with similar Gross Domestic Product per capita resulting in lesser productivity. The research objectives are: (1) To undertake an extensive literature review on CT adoption challenges; (2) To investigate CT adoption challenges unique to Vietnam's construction sector; and (3) To propose data-driven solutions for a greater rate of CT adoption.

Design/methodology/approach: A two-stage descriptive survey method was adopted in alignment with the research aim and objectives. Based on the literature review of 215 articles, a questionnaire was designed and administered to experienced CM to identify whether CT has been adopted, barriers to adoption, drivers, and the most popular CT tools. Descriptive statistics were used to summarize the characteristics of interest in the empirical dataset. SPSS-based inferential statistics was used to estimate the means, frequency counts, variance, and test the hypotheses that informed the drawing of conclusions concerning the research objectives.

Findings: The popular CT tools identified were Autodesk, Microsoft Office, and Primavera. Five most influential CT adoption barriers comprised: (1) Doubts about the impact on productivity, (2) late implementation of software at the project planning stage, (3) lack of understanding of importance and needs of CT in the construction industry (4) lack of funds during budget planning for technological investment and implementation, and (5) lack of experts required for technological change, and insufficient skills in the industry.

Practical Implications: It is expected that the findings could inform data-driven regulatory and practice reforms targeted at increasing greater uptake of CT in Vietnam with potential for replication in countries facing similar adoption challenges.

Originality: The findings are intended to support data-driven regulatory and practice improvements aimed at promoting CT adoption in Vietnam, with the possibility for replication in other countries facing comparable problems.

Keywords: Building information management, BIM; CPM; Construction technologies, Productivity, Technology adoption; Vietnam.

1.0 Introduction

Globally, construction business owners have been hesitant to adopt technologies which have been proven in other industries as being effective instruments for improving working efficiency in Architectural, Engineering, and Construction (AEC) sector (Momade et al., 2020, Durdyev et al., 2021). Ahmad et al. (2020) highlighted issues faced by Construction Managers (CM) in being able to clearly specify business models and value creation logic to meet customer value propositions and project objectives. Manoharan et al. (2020) reported that construction managers are inclined to base decision-making on short-term factors such as resources needed for operations and profitability. In the AEC sector, experience is highly prized, and it has been a primary incentive for construction firms to win new bids, complete more projects, and earn a profit in the long run.

The AEC business is currently undergoing a change, with many experienced practitioners retiring and being replaced by a younger generation highly exposed to technology. To attract younger workforce into the building industry, business models and operations must be re-engineered to be technology-driven with a view of improving efficiency and productivity, including a reduction in construction schedule, labour cost, and supplies, idle times and onsite material wastage (Durdyev et al., 2019).

Traditional construction management processes are not aligned with standard best practices and may differ across companies. By standardizing these processes using Construction Technology (CT), productivity can be improved (Zhao et al., 2022). Benefits include enhanced communication among team members and consultants. This is because CT's platform serves as a key component in ensuring real-time communication within the team using same files across all departments to price, build, inspect and manage project from inception to completion (Momade et al., 2021a).

Despite numerous benefits of CT application in construction, its uptake remains very low in the Vietnam's Construction Industry (VCI). Some studies have investigated issues with a greater adoption rate of CT in the construction sectors of other countries (Zhao et al., 2022). However, there is little research on the topic in VCI. Liu and Zheng (2019) and Olanrewaju et al. (2019) argued that the findings on related sectoral research phenomena may not be generalized easily across countries or jurisdictions due to the confounding effects of uniqueness in regulatory, socio-cultural, economic, geo-political and industrial dynamics at play in operating environment of business. Therefore, there is the need to investigate issues from VCI's perspective in the absence of such research. This research aimed to accomplish three objectives: (1) To undertake extensive literature review on CT adoption challenges; (2) to investigate CT adoption challenges unique to the VCI; and (3) to propose data-driven solutions for facilitating greater rate of CT adoption.

2.0 Literature Review

2.1 Construction Technologies in Context

There is a wide range and definitions of CT. The term could vary from applications such as drone to computer software. Liu and Zheng (2019) defined the term as referring to the collection of advanced and innovative tools, machinery, and software used during design and construction.

The contextual definition of the term for purposes of this research draws upon the definitions provided by Pour et al. (2018) as computer software or application that serves as a technological solution for enhancing construction project management practices in residential and commercial projects with a view to accomplishing project objectives in a more efficient, safe, sustainable and productive way.

2.2 Global Construction Sector and CT adoption challenges

Globally, construction industry is one of the least digitized industries in the world, which has made it difficult to tackle the problems it currently faces (Regona et al., 2022). With growth of Vietnam's economy, in particular, the construction sector, construction departments should pay attention to adoption of more efficient technologies in order to provide better services for their customers (Mabad et al., 2021). Technology can address low productivity in construction; but adoption is very low (Delgado et al., 2019). Previous studies have identified adoption challenges and implementation benefits, often quantifying the benefits to ensure that the technology isunderstandable by all major stakeholders; yet adoption rate remains low (Al-Hammadi and Tian, 2020). The construction industry's 'say:do' ratio remains poor, and this is partly due to a lack of investment in technological resources, as well as flaws in the solutions provided. Level of education and training is still low, which slows acceptance because it is preferable to keep things the way they are.

2.3 VCI and CT adoption challenges

Vietnam's Gross Domestic Product (GDP) per capita is a top economic performance index in the Asia-Pacific (APAC) region (Nguyen et al., 2019). Within APAC region, construction industry is a major contributor to social wellbeing and economic growth (NGUYEN and LUU, 2020). The construction sector has experienced phenomenal growth as a result of external factors such as the increasing supply chain relocation or diversification trend out of China and new trade agreements with European Union (Khan et al., 2020). Vietnam's sub-regional market was valued at over USD 60 billion in 2021, and it is expected to increase at an annual pace of over 8.71 percent from 2022 to 2027, ranking third in APAC region after Indonesia and Philippines (Bui et al., 2019). Vietnamese government has prioritized investments in housing projects and improving infrastructure quality, both of which impose a high demand on construction services. NGUYEN and LUU (2020) reported that Vietnam has imported more steel than Singapore, Malaysia, and the Philippines combined, indicating increased activity in the Vietnamese building sector.

Unfortunately, VCI continues to struggle with CT adoption and implementation (Van Tam et al., 2021). Wuni and Shen (2020) reported that VCI has the slowest uptake rate of technological advances in APAC region. This paper focuses on how technology can improve the current processes in VCI. The aim is to add to the knowledge base and identify major steps necessary to transition construction operations to a more machine-dominated model as advocated by Wuni and Shen (2020). It is expected that the findings from this study could be relevant to other countries facing similar concerns about how to improve greater rate of adoption of CT.

3.0 Methodology

3.1 Research Method

The descriptive survey research method was adopted for the study because the technique of observation was required for collecting empirical data which comprised opinions of survey respondents (Wuni and Shen, 2020). However, Alturki (2021) 'research onion' framework provided an appropriate, systematic and strategic approach to the overall conception, design and implementation of the research. Research onion framework relevance is evident in the specifics about the research aim and objectives, construction knowledge domain, acceptance of value addition in sector and research relevance, nature of empirical data, acceptable data gathering approach and analysis, scale of research instrument used, and interpretation and validity of findings.

This study like every other research has its set of limitations. It was based on perspectives of experienced CM who have firsthand experience in the implementation, adoption, and management of CT in their respective projects and firms. The study was limited to project management related CT that impact directly on the 10 knowledge areas that comprise the Project Management Body of Knowledge (PMBOK, 2018), namely, cost, quality, schedule, resource, safety, risk, human resource, communication, contract, and project setup including stakeholder management. The scope of the software referenced in this study was limited to what was popularly used in VCI within the delineated timeframe for fieldwork. The study timeline is critical and research articles from 2005 – 2022 were taken into consideration. If same keywords are used later a different result will be achieved due to research timeline difference.

Given this study is the first in VCI, it is expected that the findings would be of great value to researchers, learners, practitioners and policymakers, and other stakeholders who may be interested in finding new ways to increase CT adoption and implementation. Despite the identified limitations, the findings could provide the starting point for further research in the region as well as inform wider debate on the issues going forward.

3.2 Secondary and primary data gathering stages

Following the approach adopted by Nnanna et al. (2021), the first phase of this research involved a thematic analysis of the secondary data collated from a systematic review of cognate and contemporary studies on the topic. Scopus was the only scientific database from where articles were reviewed mainly due to ensuring quality of data and more accurate results.

Keywords used to search for relevant and current articles comprised "Adoption", "Construction", "Challenge", "Factors", "Productivity" AND Technology"

A total of 2,140 articles were found in relation to the research topic. After a thorough review of each article, only 215 were found relevant to current research. Advanced tools such as Bluebeam were used to review article contents and ensure a quicker collation of important information. The following was extracted from the selected articles:

(1) Administrative information such as name of authors, affiliation details, location of study and total number of identified factors
(2) Data analysis to understand major objectives, key findings and impact to the body of knowledge

(3) Data collection method to understand target of research, how it was successful in method used and major research limitations

Major findings have been inserted in Tables 1 and 2. Table 1 identifies major CT tools. Table 2 lists major barriers to CT adoption identified in previous studies. Findings based on geographic regions were also collated.

Second phase of the research focused on developing questionnaire as research instrument for primary data gathering with VCI as the delineated study region. To explore relevance and relative importance of constructs identified during the first phase, a list of questions was compiled to elicit rating responses from experienced CM registered with Vietnam's chapter of the Asian Pacific Federation of Project Management.

3.3 Empirical data analytical approach

The multi attribute utility analysis adopted for the empirical data analysis drew upon the recommendations of Iroha et al. (2021), given the nature of the research objectives, distribution-free nature of the empirical data and the ordinal scale of measurement employed in the survey research instrument. The following comprise the key parameters used in the empirical data analyses.

The importance index (II) was used to compute combined rating responses received from CM. Effect size was determined by dividing the difference between sample statistics with the standard error. The quotient was subsequently used to determine relative levels of importance of the identified major factors. Test range was determined to be higher than 171 (for sample size of 5000 CM responses and a margin of error of ±5%).

The Cronbach's alpha, a reliability coefficient, was calculated and used to ascertain whether the survey responses and scale of instrument used were internally reliable and consistent. The analytical approach drew from similar approach adopted by Murat et al. (2020) in evaluating human efficiency drivers for construction labour productivity. Equations 1 and 2 show expressions for deriving Cronbach's alpha and the Importance Index.

Using the Cronbach's alpha statistic, the degree to which responses to survey questions were correlated were analyzed. Result was used to estimate percentage of variance that is systematic or consistent across a set of responses. An index value of 0.7 is acceptable, while a value of 0.8 or greater indicates good internal consistency (Zhao et al., 2022). Cronbach's alpha coefficient is calculated using Equation 1

$$\alpha = \frac{N.\bar{c}}{\bar{v} + (N-1).\bar{c}} \quad (1)$$

where,

α = Cronbach's alpha
N = the number of factors being rated.
$\bar{C}$ = the mean covariance between factors sets.
$\bar{v}$ = the mean variance

The Cronbach's alpha was analysed from the responses using the SPSS version 24 software. Also, the coefficient of determination was calculated using SPSS version 24 software; the result was found to be 0.86.

Ranging from zero to one, the importance index (II) indicates how significant a particular attribute is in comparison to other attributes. Equation 2 provides an expression for evaluating the II of each factor rated by respondents within a set of variables.

$$Importance\ Index = \frac{3n_1 + 2n_2 + 1n_3}{3(n_1 + n_2 + n_3)} \tag{2}$$

where,

n_1 = High importance
n_2 = Moderate importance
n_3 = Low importance

There is no requirement for data distribution to be normal or homogeneous in order to use Spearman's rank correlation coefficient (Zhao et al., 2022). Spearman's correlation coefficient is used to ascertain whether two different variables are associated with each other, as distinct from being linearly correlated. Based on Spearman's correlation theory, a variable's score must be monotonically related to another variable for correlation significance, and the two variables must be measured on an ordinal scale. Correlations among the numerous categories of respondents in this study were evaluated using Spearman's coefficient, using Equation 3.

$$r = 1 - [\frac{6\sum d^2}{n^3 - n}] \tag{3}$$

where,

r = Spearman rank correlation coefficient between two factors;
d = difference between ranks assigned to factors;
n = number of pairs of rank (equals the number of attributes, which is 40 in this research)

Correlation coefficient ranges from -1, which means a perfect negative relationship (disagreement), to +1, which means a perfect positive relationship (agreement).

Based on analysis of results, limitations were identified, and data driven solutions were proffered. Future studies related to adoption of CT were recommended.

4.0 Data Presentation and Discussion of Results

4.1 Technology Tools and Users

To understand the current tools in use in the Vietnam's for implementing construction projects, the authors chose to seek the assistance of the CT department in construction firms through online questionnaire. Through their assistance, a table was created to list down all the technologies currently in adoption and the number of users applying the tools on a regular basis. The tools with highest number of users were used for survey and the basis for discussion of results.

Parameters for selection of tools are as follows:

a. Tools which had a direct interaction with ongoing construction projects were listed.
b. Tools which were used in the construction project management were listed. In construction cycle and terminology, this meant Design, Procurement, Construction and Closing Phase related tools.
c. List was created from Vietnam's perspective. Authors chose top tools with highest number of users for questionnaires and discussion in research article.

Table 1 List of construction technologies

CT Software	Software type
Aurigo, Build, Coconstruct, Corecon, Dropbox, Kitework, Microsoft Office, Monday Construction, Procore Technologies, Viewpoint and Workflowmax	Document control
AutoCAD, Bluebeam	Design
Bridgit, Fieldwire	Workforce
Building Connected	Tender
Microsoft Project, Oracle Primavera	Schedule
Sage 100 Contractor	Accounting
Smartsheet	Tasks

4.2 Findings from Previous Studies

Survey of contemporary literature resulted in the following findings:

It can be noted from Figure 1 that most studies have been completed in the following countries: Nigeria (7 studies), Malaysia (6 studies), Australia (5 studies), USA (5 studies) and India (4 studies). USA and Australia are developed countries, while India, Malaysia and Nigeria are developing countries with the bulk of construction work being carried out using manual labour. Research gaps exist in South America, Europe and Oceania, as there were no studies conducted in these continents. Further study of the South American continent can provide CM with guidance on how to focus their attention, act upon, and control the critical factors influencing CT adoption. South American studies can provide a broader and deeper perspective on the motivational factors affecting performance.

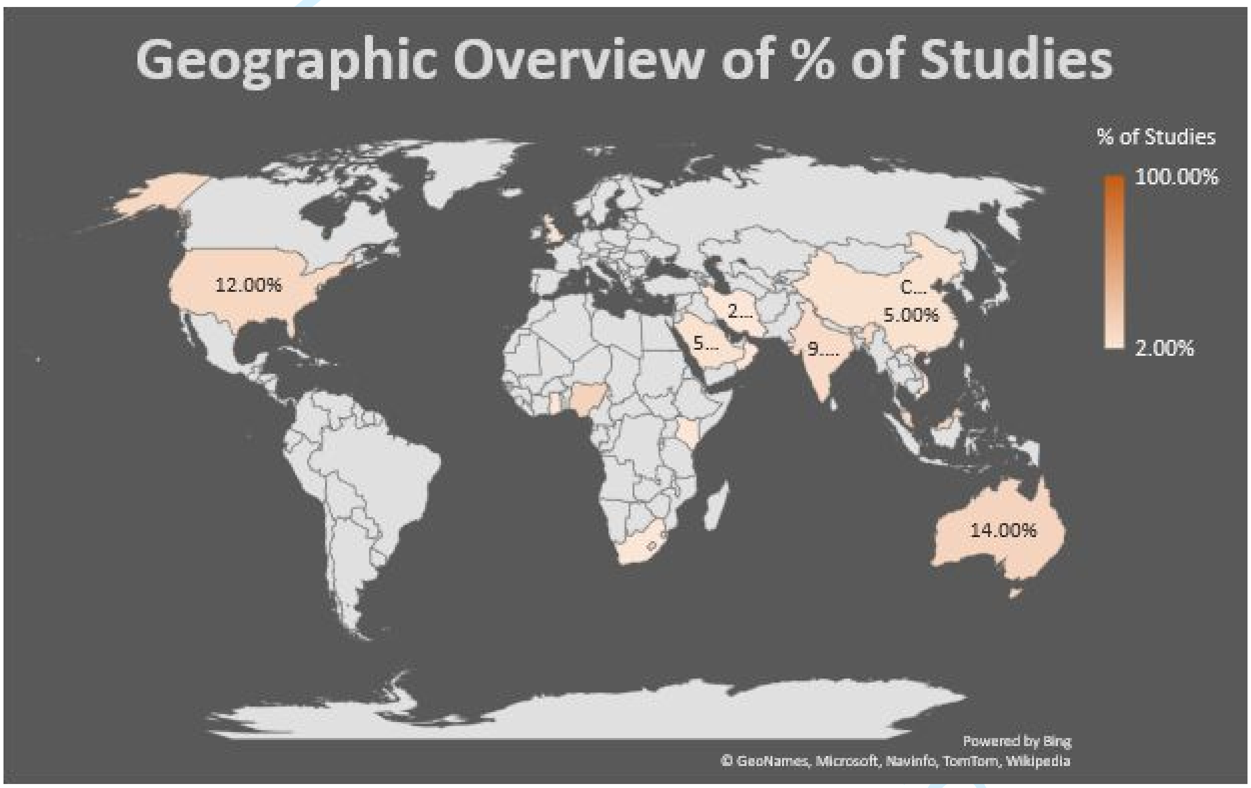

Figure 1: Geographic Overview of % of Studies

There are many challenges faced in adoption of technologies as discussed by past researchers. Below is a summary of top challenges faced in CT adoption as analysed from the literature. Researchers ranked various factors differently as presented in Table 2. In the table, only factors ranked among the top 5 are shown. A rating of '1' represents the most important factor, while '5' represents the least important (among the five most important factors). Based on the aggregation of the ranks, the , the following conclusion has been reached as the most frequently mentioned factors influencing CT adoption : (1) High set up cost; (2) Lack of available information on technology reliability, implementation, and benefits; (3) Lack of support from top management;

(4) Lack of human expertise, capability, client knowledge and training and; (5) Lack of institutional policies and guidelines.

Factors were grouped into seven different categories, which are: G1: Regime-associated factors; G2: Individual-associated factors; G3: Data-associated factors; G4: Market-associated factors; G5: Finance-associated factors; G6: Business associated factors and G7: IT associated factors. These categories were used by other researchers in their studies (Qin et al., 2020). Table 2 reveals the most influential factors and categories. For succinctness, only the most influential factor is highlighted in each category. For the G7 category - "software capability does not match project requirements"; for the G6 - "ease of maintenance, productivity"; for the G5 – "high set-up cost"; for the G4 - "importance or relevance of the software to the internal needs"; for the G3 – "lack of available information on technology reliability, implementation, and benefits"; for the G2 – "lack of human expertise, capability, client knowledge and training"; and for the G1 - "lack of institutional policies and guidelines"..

Table 2 Influential Factors Identified in Literature Review

G	Factors	Rank by Researchers	∑
7a	Software capability does not match project requirements	(1) 33, 6, (2) 37, (3) 22, (4) 17, 38, (5) 39, 8	**9**
6a	Ease of maintenance	(5) 1	**1**
6b	Productivity did not improve	(3) 2	**1**
5a	High set up cost	(1) 43, 13, 34, 2, 36, 24, 12, (2) 6, 8, (3) 30, 27, (4) 41	**12**
5b	Risks in implementation	(1) 19, 20, (2) 16, (4) 14, 1, (5) 18	**6**
5c	Project complexity did not allow for new software to be implemented	(1)16, 17, (2) 2, 18, 12	**5**
5d	Long lead time required for full-scale implementation	(1) 7, (2) 11, (3) 12, (4) 13	**4**
5e	Legal and contractual constraints on adopting technology	(2) 4	**1**

G	Factors	Rank by Researchers	∑
5f	Lack of tax related benefits, return on investment not clear	(1) 21, 30, (2) 40, 9, (3) 15, 17, (5) 41, 42, 24, 3	**10**
5g	High training and running costs	(1) 15, 42, 27, (2) 34, 43, 13, (3) 4, (4) 12, 6 (5) 36	**11**
4a	Importance of software not clear / internal staff needs do not match software requirements	(1) 10, (3)14, (4) 15, 3	**4**
4b	Business agility / expansion	(2) 3, (3) 9	**2**
3a	Lack of available information on technology reliability, implementation, and benefits	(1) 8, 41, 25, 40, 39, (2) 5, 35, 33, 28, (3) 26, 18, 42, 16, 11, 32, 38, (4) 34, 30, 21	**19**
3b	Lack of knowledge and understanding of use	(2) 24, 25, (4) 26, 19, 27, 11, (5) 28, 29	**8**
3c	Lack of understanding	(1) 22, 1, (2) 36, 32, (3) 28, 13, 31, (4) 24	**8**
3d	Lack of funds during budget planning for technological advances and implementation	(1) 5, (2) 10	**2**
3e	Late implementation of software in project planning	(5) 5, 6	**2**
3f	Lack of experts required for technological change and insufficient skills in the industry were identified	(3) 3	**1**
2a	Lack of human expertise, capability,	(1) 35, 11, 14, (2) 29, 21, 19, 31, 7, 26, (3) 34, 24,	**26**

G	Factors	Rank by Researchers	∑
	client knowledge and training	10, 43, 33, 41, 25, 40, 20, 36, (4) 42, 39, 28, (5) 13, 27, 4, 9	
2b	Lack of support from top management	(1) 38, 9, 31, 26, 37, (2) 14, 42, 15, (3) 6, 8, 39, 1, 5, (4) 35, 20, 10	**16**
2c	Resistance to change	(1) 18, 4, (2) 20, (3) 7, (5) 30, 31, 10, 12	**9**
2d	Company culture on adoption of technologies and innovation strategies	(2) 1, (3) 21, (4) 9, 22, (5) 2, 15	**7**
2e	Staffing shortage on adoption of technology requires new roles/responsibilities	(4) 7, 8	**2**
1a	Lack of institutional policies and guidelines	(1) 29, 32, 28, (2) 41, 39, (3) 35, 19, (4) 18, 4, 36, 16, (5) 26, 33	**13**
1b	Lack of government/client mandate	(2) 30, (4) 31, 32, 2, 33, (5) 20, 34, 35	**8**

Hong et al. (2016) – 1, Pan et al. (2020) – 2, Nguyen et al. (2015) – 3, Abubakar et al. (2014) – 4, Wuni and Shen (2020) – 5, Attarzadeh et al. (2015) – 6, Zahrizan et al. (2013) – 7, Liu et al. (2010) – 8, Shehzad et al. (2019) – 9, Sargent et al. (2012) – 10, NGUYEN and LUU (2020) – 11, Borhani (2016) – 12, Ahuja et al. (2020) – 13, Fernandes et al. (2006) – 14, Talukder (2012) – 15, Saleh and Alalouch (2020) – 16, Ahuja et al. (2010) – 17, Osunsanmi et al. (2020) – 18, Thomas and Abraham (2020) – 19, Saka and Chan (2020) – 20, Usman and Gidado (2015) – 21, Foroozanfar et al. (2017) – 22, Peansupap and Walker (2005) – 23, Chan et al. (2018) – 24, Noghabaei et al. (2020) – 25, Babatunde et al. (2020) – 26, Vidalakis et al. (2020) – 27, Amuda-Yusuf et al. (2020) – 28, (Ahuja et al., 2009) – 29, Muthusamy and Chew (2020) – 30, Al-Hammadi and Tian (2020) – 31, Omamo (2012) – 32, Lam et al. (2010) – 33, Nnaji and Karakhan (2020) – 34, Hamma-adama et al. (2020) – 35, Zaini et al. (2020) – 36, Ding et al. (2015) – 37, Doumbouya et al. (2016) – 38, Almashjary et al. (2020) – 39, Olaniyan et al. (2020) – 40, Qin et al. (2020) – 41, Abbasnejad et al. (2020) – 42 Akmam Syed Zakaria and Amtered El-Abidi (2020) – 43. Foroozanfar et al. (2017) – 44, Ahuja et al. (2009) – 45, Sepasgozar and Davis (2018) – 46, Momade et al. (2021b)– 47

Construction industry requires new thinking. A more harmonious working environment can be created by adopting strategies to improve level of integration. The following are some recommendations summarized in previous studies for promoting greater rate of CT adoption in the building industry: (1) Synergy of all building players to create an implementation strategy. (2) Government support and initiative. (3) Implementation of adoption model / infrastructure / culture.

(4) Study of organizations where adoption rate is higher to understand emerging trends. (5) Comparison of results with other industrial sectors. (6) Use of more participants during research for better validation of findings. (7) Promoting higher levels of trust and awareness of the technology.

Major limitations in previous studies have been discussed earlier in the preceding sections of this article. Current findings are a step further in identifying major barriers in Vietnam.

4.3 Identification of factors at VCI

Basic measure of survey data is descriptive statistic. Purpose of this study was to identify influential factors in implementation of technology in VCI. A total of 226 valid questionnaires were received. Demographics of the respondents is shown in Table 3. It was found that most respondents were male (87.6%) compared to female (12.4%). This result should be expected since most of construction workforce is dominated by males. Most respondents were educated (with 94.7% of respondents earning bachelor's, master's or doctorate degrees). In terms of work experience, most respondents had 1-10 years, though it should be noted that younger generation has more hands-on experience with technology. Majority of respondents worked for a general contractor or a consultancy firm. The survey covered a wide variety of construction related roles which allowed for a comprehensive investigation of the issues.

Table 3 Respondents' demographics

Variables	**Categories**	**Frequency**	**Percentage**
Gender	Male	198	87.6%
	Female	28	12.4%
Education level (degree)	Diploma	12	5.3%
	Bachelor's	161	71.2%
	Master's	47	20.8%
	Doctorate	6	2.7%
Work experience (years)	1-5	142	62.8%
	6-10	49	21.7%
	11-15	27	11.9%
	16-20	5	2.2%
	>20	3	1.3%
Organizational Involvement	Client	20	8.8%
	General Contractor	71	31.4%
	Sub-contractor	21	9.3%
	Supervision	43	19.0%
	Consultant	71	31.4%
Role in project	Construction manager	27	11.9%
	Site manager	33	14.6%

Site supervisor	18	8.0%
Site engineer	35	15.5%
Designer	46	20.4%
Architect	38	16.8%
Estimator	24	10.6%
Company manager	5	2.2%

The next section of the survey explored the extent of CT tools application in AEC industry. Respondents rated levels of use intensity of the identified CT tools as proxies for relative importance, with the rating scale ranging from 1 to 3 (1 being low and 3 being high level of use intensity). From the analysed mean ratings in Table 4, most respondents rated Autodesk tools as highly important giving its high use intensity level; ranking of the mean ratings shows that Autodesk achieves the highest rank of 1. Microsoft office tools achieved a ranking of 2, though trailing Autodesk by a narrow margin in the mean rating scores. Given that Vietnam is a developing country with most of the construction projects completed on a very low-profit margin, the adoption of CT tools is limited. CT tools have been found to improve project productivity and efficiency in other countries. Although these improvements add value to projects, it is difficult to put a financial value to CT adoption. In comparison, a study commissioned by Ezeokoli et al. (2016) revealed that 54% of developing country respondents utilized 2D CAD exclusively, while 12% utilized 3D CAD, 20% (2D) and 14% 3D CAD. This contrasts with a related study conducted in a developing country by Sawhney et al. (2014), which showed 57% of users implemented 3D, while 8.6% don't utilize CAD at all.

Table 4 The Extent of Using CT Tools

Tools	Mean	Rank
Autodesk	2.51	1
Microsoft Office	2.38	2
Primavera	1.99	3
Microsoft Project	1.56	4
Procore	1.43	5
Sage	1.42	6
Bluebeam	1.36	7
Dropbox	1.35	8

Further investigations also explored what the device or system which served as a medium for use of CT tools in VCI. Results in Table 5 showed that most respondents rated computer as the most popular medium of use. This contrasts with earlier studies in other countries where mobile phone is the most popular medium for CT tool application in the construction industry (Liu et al. 2019). However, it is interesting to note that as more CT tools are developing friendly mobile phone applications, many users in the construction industry are beginning to use the mobile phone-based CT applications including Procore, MS Office, and AutoCAD (Liu et al., 2019)

Table 5 Method of Use of CT Tools

System	Frequency	Percentage
Computer	186	82.3%
Phone	37	16.4%
Tablet	3	1.3%

There are many benefits of CT tools adoption (Atkinson et al., 2021). Although most benefits cannot be directly related to financial savings, efforts were made to survey the number of hours spent/saved using CT tools. Stanford University Center for Integrated Facilities Engineering calculated benefits from BIM implementation in 32 construction projects are up to unbudgeted change is eliminated by 40%, cost estimation accuracy is improved by 3%, time taken to generate a cost estimate is reduced by up to 80%, conflicts can be detected in time to save up to 10% of the contract value, and project time can be reduced by up to 7% (Osunsanmi et al., 2020). In accordance with respondents, most spend 3-4 hours daily using CT tools. In terms of time savings, most users agree it saves them 1-2 hours in a day. Table 6 compares the time spent/saved using CT tools.

Table 6 Number of Hours Spent / Number of Time Saved using CT Tools

Time Spent on CT Tools		**Time (Minutes)**	**Time Saved using CT Tools**	
Frequency	Percentage		Frequency	Percentage
6	2.7%	< 30	58	25.7%
21	9.3%	30 - 60	70	31.0%
23	10.2%	120 - 240	33	14.6%
22	9.7%	240 - 360	19	8.4%
92	40.7%	360 - 480	21	9.3%
62	27.4%	> 480	25	11.1%

Table 7 indicates what most respondents are using CT tools for in VCI. Most users agree CT tools are highly being used for construction operations, interpreting drawings and for estimation purpose. The tools are used for all phases/duration of project.

Table 7 Use of CT Tools

Scope of Work	**Frequency**	**Percentage**
Request for Information	35	15.5%

Estimating	80	35.4%
Drawings	91	40.3%
Communication	33	14.6%
Construction Operations	107	47.3%
Resources Management	49	21.7%
Bidding	32	14.2%
Submittals	63	27.9%
Specifications	14	6.2%

Major research purpose was to recognize the barriers influencing the CT implementation in VCI. The most influential were: (1) Unknown impact on productivity, (2) Late implementation of software in construction projects, (3) Lack of understanding on importance and needs in construction industry (4) Lack of funds during budget planning for technological advances and implementation (5) Lack of experts required for technological change and insufficient skills in industry were identified.

When barriers identified in Vietnam are compared to previous study findings, it can be noted barriers are evolving, and new challenges are found in CT adoption. Companies have started to implement new technologies available (van Wyk et al., 2021). Issue they're facing is on what value it is bringing to projects and overall company processes. Return of investment and hence productivity analysis is something that cannot be measured before or during implementation. Data is required for years to compare how previous processes were not as cost effective as newer ones with aid of technology. Currently there is no software in market that can cover all processes. Hence, there is an invisible wall between departments. New programs such as Procore are trying to tackle barrier by merging with other software in market, but it has yet to reach maturity. Once there is a continuous flow of information and departments are linked with one central platform, it will allow a more comprehensive understanding of productivity.

Construction industry unlike manufacturing and other respective industries it has projects that lasts for years. Software implementation benefits when it is implemented in earlier stages of project. Unfortunately, most of the failures captured are in projects that are attempting to implement halfway. First, there was no budget planned. Secondly, high costs are incurred for training, transferring all information to new system, and ensuring whole team is on board. Most of the CM are now refraining from this exercise to avoid high risks of failures in overall performance of respective projects.

The current industry is suffering from understanding what software to implement and its impact on current processes. Construction industry is highly occupied and does not have time to stop and train itself on newer/better solutions. University and college programs are only picking up pace now. Over years, programs have been limited to Microsoft Office, Microsoft Project, Primavera and few other software trainings only. Industry overall is benefiting from government mandates to improve on efficiency.

Table 8 Major barriers affecting the Adoption of CT

Factors	Mean	SD	Rank
6b	2.75	0.463	1
3e	2.74	0.48	2
4a	2.73	0.484	3
3d	2.72	0.481	4
3f	2.69	0.51	5
2a	2.68	0.529	6
2e	2.68	0.548	7
3b	2.67	0.518	8
5c	2.63	0.554	9
5g	2.58	0.585	10
7a	2.58	0.546	11
3a	2.57	1.432	12
2b	2.53	0.583	13
2d	2.52	0.575	14
2c	2.5	0.56	15
5d	2.49	0.576	16
4b	2.49	0.598	17
1a	2.49	0.642	18
5a	2.49	0.598	19
5f	2.48	0.606	20
5b	2.48	0.634	21
3c	2.46	0.582	22
5e	2.42	0.684	23
6a	2.25	0.643	24
1b	2.24	0.644	25

5.0 Conclusion

CT have emerged as powerful tools that can be used to work more efficiently in AEC applications. Reportedly, technologies such as AI as solving complex problems can be greatly enhanced by tools. Implementation of CT in AEC can reduce time, manpower, and material requirements, which will result in lower construction costs. A critical review of past studies was conducted, and most influential recurring factors were identified by the authors in VCI. From study made, authors conclude influential factors in adoption of measurement, evaluation, and discussion of CT are significant aspects.

Construction continues to be impacted by changes and innovations resulting from rapid advancement of technology. CT plays an important role in continued digitalization of industry. Based on findings, authors have proposed the following recommendations to foster CT adoption in construction projects in Vietnam:

Vietnam's government must allocate more budget and introduce mandates to promote CT adoption. Government should provide tax deductions, organize conferences, and require technology in all public projects. This will address the factor 3d. Government mandates will create awareness for CT potential and address cost savings in long run. It will provide more data for researchers and increase sample size for review, allowing better tools to be created in long run and improve efficiency of the projects.

Colleges and universities must review their curriculum to become the center for learning latest technologies in place. Companies should partner with University Scholars to ensure graduates are equipped with latest technologies in place. This will address the factor 3f. Educational institutions play a significant role in being first to introduce technologies that are most used in different types of construction projects. Having a knowhow of the tools and a good understanding of its abilities in the back of your mind will benefit when problems arise.

Project owners should encourage contractors and all respective stakeholders to find more efficient methods (known as value engineering). Monthly training programs should be implemented at construction office to learn better methods. This in turn will address factor 3e. It is easier to implement construction technologies during planning stage. The consultants play a key role in understanding and making projects more efficient by using software's. It aids in saving costs. Contractors need to maintain consistency in implementation by budgeting for it in advance and having training programs for new staff members to continue to use and connect dots from start to finish.

To facilitate learning and adoption of CT during construction projects, professional agencies and construction enterprises should procure all necessary CT software. Construction companies should use data to create strategies which will align the company's vision with software implementation. Models and framework can be created specific to scope of work of business.

It is expected the current article can serve as a framework for similar studies in construction industry in other regions, based on methodology proposed in this study for identification of factors in CT adoption in AEC. By doing so, it can help to improve overall productivity of construction projects by facilitating efficient planning and management. More studies will validate accuracy of results obtained in this study.

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The authors wish to express gratitude to the editors and reviewers for their time and effort in reviewing our manuscript. We hope the changes listed below have made the manuscript suitable for publication.

Once more, thank you.

Reviewer's/Editor's comment	Authors' response
Editor	
In addition, I note that the manuscript word count is now well over our suggested limits of 8000 words. Please look to reduce this in line with our guidelines.	The article word count has been reduced to 7,988 words.
Reviewer 1: Minor Revision	
the abstract can still be improved to be shorter and concise	The abstract has been rewritten and shortened.
there are citations in the manuscript that are missing from the reference list, for instance, Haji Karimian et al., 2019	All missing references have been inserted.
the citations require review for correctness and uniformity. You only require the first name and the year, e.g Dulaimi, Y. Ling et al. 2002, and others	All citations have been formatted to emerald Harvard which contains first name and the year only.
How did the study adopt a mixed method?	The study comprises of both qualitative and quantitative methods, which are literature review to identify the challenges and quantify their significance level in the Vietnamese construction industry upon the opinion-based feedback provided by the construction professionals.
the citation provided to support the mixed method does not align with this position.	The citation has been updated.
How is section 4.1 achieved? Is there any justification for this choice?	Online questionnaire was used.
Authors should ensure all citations in section 4.2 be in the reference	All citations have been added in the list of reference.
Section 4.2 can be presented to start from the countries before the factors	Section 4.2 has been revised to start from countries followed by factor review
To achieve some flow, the authors might want to consider classifying section 4.2 as the literature review section whose findings were adopted in the questionnaire.	Thanks for your feedback. However, it would be better to keep it in its original section as it is part of the results even though they were obtained as a result of a literature review.
the criteria adopted for restricting the studies in section 4.2 should be outlined. Also, the year of coverage should be stated. Finally, the authors can state when the data was achieved as same keywords can be adopted, and a different result will be achieved due to time difference.	Limitation has been written and the timeline of 2005 – 2022 has been provided.
Having "productivity" in the keywords might have titled the results of the search:	Productivity has been inserted as a keyword
Reviewer 2: Accept	

Page **1** of **1**

Factors influencing Adoption of Construction Technologies in Vietnam's Residential Construction Projects

Abstract

Purpose: Vietnam's Construction Technology (CT) adoption is low when compared to other countries with similar Gross Domestic Product per capita resulting in lesser productivity. The research objectives are: (1) To undertake an extensive literature review on CT adoption challenges; (2) To investigate CT adoption challenges unique to Vietnam's construction sector; and (3) To propose data-driven solutions for a greater rate of CT adoption.

Design/methodology/approach: A two-stage descriptive survey method was adopted in alignment with the research aim and objectives. Based on the literature review of 215 articles, a questionnaire was designed and administered to experienced CM to identify whether CT has been adopted, barriers to adoption, drivers, and the most popular CT tools. Descriptive statistics were used to summarize the characteristics of interest in the empirical dataset and SPSS-based inferential statistics to estimate the means, frequency counts, variance, and test hypotheses that informed the drawing of conclusions concerning the research objectives.

Findings: The popular CT tools identified were Autodesk, Microsoft Office, and Primavera. The most influential CT adoption barriers: (1) Unknown impact on productivity, (2) Late implementation of software in construction projects, (3) Lack of understanding of importance and needs in the construction industry (4) Lack of funds during budget planning for technological advances and implementation (5) Lack of experts required for technological change, and insufficient skills in the industry.

Originality: The findings are intended to support data driven regulatory and practice improvements aimed at improving CT adoption in Vietnam, with the possibility for replication in other countries facing comparable problems.

Purpose: Vietnam's construction has failed to adopt Construction Technology (CT) in comparison to other countries with similar Gross Domestic Product per capita resulting in lower productivity. There is little research on the barriers to greater uptake of CT in the Vietnam's construction industry. This research aimed to accomplish three objectives: (1) To undertake a literature review of extent CT adoption challenges in the construction sector; (2) To investigate CT adoption challenges unique to the Vietnam's construction sector; and (3) To propose data-driven solutions for facilitating greater rate of adoption of CT.

Design/methodology/approach: A two-stage descriptive survey research method was adopted in alignment with the research aim and objectives. A comprehensive literature review of 215 related articles were conducted to obtain construct for the second stage questionnaire survey. Using the constructs gleaned from previous studies and additional insights provided by experts in the construction industry, a questionnaire was designed and administered to experienced construction project managers in the Vietnam's construction industry with a view to eliciting responses to questions about the extent of adoption of CT tools, barriers, drivers, and the most popular CT tools. Descriptive statistics were used to summarize the characteristics of interest about the empirical dataset, while SPSS-based inferential statistics were used to estimate the means, frequency counts and variance, as well as test hypotheses that informed the drawing of conclusions in relation to the research objectives.

Findings: Results about the popular CT tools used in the construction industry showed that Autodesk, Microsoft Office and Primavera were the most popular. Results about key unique

factors influencing CT adoption in the Vietnam's construction industry revealed the following as the most influential: (1) Unknown impact on productivity, (2) Late implementation of software in construction projects, (3) Lack of understanding on importance and needs in construction industry (4) Lack of funds during budget planning for technological advances and implementation (5) Lack of experts required for technological change, and insufficient skills in the industry.

Originality: It is expected that the findings could inform data-driven regulatory and practice reforms targeted at increasing greater uptake of CT in Vietnam with potential for replication in countries facing similar adoption challenges.

Keywords: Building information management, BIM; Construction project managementCPM; Construction technologies, Productivity, Technology adoption; Vietnam.

1.0 Introduction

Globally, construction firm business models have been hesitant to adopt technological improvements that have developed in other industries as effective instruments and can be deployed to improve working efficiency in Architectural, Engineering, and Construction (AEC) sector Globally, business models of construction firms have been very slow in the uptake of technological advances that have emerged in other sectors as powerful tools that can be applied to enhance working more efficiently in the Architectural, Engineering and Construction (AEC) sector (Momade et al., 2020). Previous study by Ahmad et al. (2020) highlights significant problemsissues faced by- construction managersConstruction Managers (CM) in being able to clearlyto clearly specify business models and value creation logic to meet customermeet customer value propositions and project objectives. In an earlier study, Manoharan et al. (2020) found thatreported construction managersCM are more inclined to base decision-making on short-term factors such as resources needed for operations and profitability. In AEC sector, experience is highly prized, and it has been a primary incentive for construction firms to win new bids, complete more projects, and earn a profit in the long run. The AEC business is currently undergoing a change, with many experienced practitioners retiring and being replaced by a younger generation highly exposed to technology.. Experience is highly valued in AEC industry and has been a major driver for construction companies to win new bids, complete more projects and make profit in the long-run. The AEC industry is currently going through a transition whereby many experienced practitioners are retiring and being replaced by a younger generation that is highly exposed to technology in their daily lives. In order tTo attract more workforce towardswards the building industry, it is critical that business models and operations arbusiness models and operations must be re-engineered to be technologybe technology-driven with a view to of improving efficiency and productivity, including a reduction in- -construction schedule, cost of labor cost, and supplies, idle times and onsite material wastage (Darko et al., 2020).(Tayfur et al., 2013, Darko et al., 2020).

The tTraditional construction management processes are not aligned with standard best practices and may differ from each company to company. By standardizing these processes using Construction Technology (CT), several benefits could be achieved including improvement in productivity and efficiency in the projectsproductivity can be improved (Zhao et al., 2022). Benefits could also include enhanced communication among team members and consultants. This is because CT's platform serves as a key component in ensuring real real-time communication within the team using the same files across all departments to price, build, inspect and manage the project from inception to completion (Momade et al., 2021a)).

Despite the numerous benefits of CT application in construction, its uptake remains very low in the Vietnam's construction sectorVietnam's Construction Industry (VCI) and indeed many other construction sectors (Chan et al., 2020). Some studies have investigated issues with a greater adoption rate of CT in the construction sectors of other countries (Zhao et al., 2022)(Bui et al., 2019, Zhao et al., 2022). However, there is little research on the topic in the Vietnam's construction sectorVCI context. Liu and Zheng (2019) and Olanrewaju et al. (2019) argued that findings on related sectoral research phenomena may not be generalized easily across countries or jurisdictions due to the confounding effects of uniqueness in the regulatory, socio-cultural, economic, geo-political and industrial dynamics at play in the operating environment of business. Therefore, there is the need to investigate the issues from the Vietnam's construction sectorVCI's perspective in the absence of such research. To contribute to narrowing the existing knowledge gap, this research aimed to accomplish three objectives: (1) To undertake extensive literature review on CT adoption challenges; (2) To investigate CT adoption challenges unique to the VCI; and (3) To propose data-driven solutions for facilitating greater rate of CT adoption.(1) To undertake a general review of extant literature relating to CT adoption challenges in the construction sector; (2) To investigate CT adoption challenges unique to Vietnam's construction sector; and (3) To propose data driven solutions to facilitate the greater rate of adoption of CT in Vietnam's construction sector.

2.0 Literature Review

2.1 Construction Technologies in Context

There is a wide range and definitions of CT. The term could vary applications such as drone to a computer software. Liu and Zheng (2019) defines the term as referring to the collection of advanced and innovative tools, machinery, and software used during design and construction.

There is a wide range of scope and definitions of 'construction technologies' (CT). The term could vary applications such as drone to a computer software. Liu and Zheng (2019) defines the term as referring to the collection of advanced and innovative tools, machinery, and software used during the design and construction phases of a construction project to advance design and construction operations for enhanced efficiency and productivity, and may include algorithms, and robotized, autonomous or semi-automated construction plant and equipment.

The contextual definition of the term for ~~the~~ purposes of this research draws upon the definitions provided by ~~Skibniewski and Zavadskas (2013) and~~ Pour et al. (2018) as computer software or application ~~that~~ serves as a technological solution for enhancing construction project management practices in residential and commercial projects with a view to accomplishing ~~the~~ project objectives in a more efficient, safe, sustainable and productive way.

2.2 Global Construction Sector and CT adoption challenges

Globally, construction industry is one of the least digitized industries in the world, which has made it difficult ~~for it~~ to tackle the problems it currently faces (Regona et al., 2022)~~.~~. With ~~the~~ growth of Vietnam's economy, in particular, the construction sector, ~~the departments in~~ construction ~~companies~~ departments should pay attention to ~~the~~ adoption of more efficient technologies ~~to~~ hence provide better services for their customers (Mabad et al., 2021). Technology can address low productivity in construction; but adoption is very low (Delgado et al., 2019). Previous studies have identified ~~the~~ adoption challenges ~~faced in adoption~~ and ~~the key~~ implementation benefits ~~of the implementation~~, often quantifying to ensure it's understandable by all major stakeholders, but ~~the~~ adoption rate remains low (Al-Hammadi and Tian, 2020). "Establishment setting a standard for future design and construction," "increased efficiency," "enhanced user health and well-being," "non-renewable resources conservation," and "reduced overall project lifetime costs," according to Darko et al. (2018), who discovered a common pattern in other locations. The construction industry's say:do ratio remains poor, and this is partly due to a lack of technological resources, as well as flaws in solutions provided. Level of education and training is still low, which slows acceptance because it is preferable to keep things the way they are.

~~Darko et al. (2018) identified the following five major influential factors which are the drivers in adoption in Ghana and a common theme has been found in other regions: "Establishment setting a standard for future design and construction", "raised efficiency", "improved user health and well-being", "non-renewable resources conservation", and "reduced whole project lifecycle costs". The say:do ratio in the construction industry remains low and the pool of technological resources are partially to blame as well as there are shortcomings in the solutions available. The level of education and training remains low which does hinder the adoption rate as its preferred to keep things as they are.~~

2.3 ~~Vietnam's Construction Sector~~VCI and CT adoption challenges

Vietnam's Gross Domestic Product (GDP) per capita is a top economic performance index in ~~the~~ Asia-Pacific (APAC) region (Nguyen et al., 2019). Within ~~the~~ APAC region, ~~the~~ construction industry is a major contributor to ~~the~~ social wellbeing~~-~~ and economic growth (NGUYEN and LUU, 2020). The construction sector ~~within the region~~ has experienced phenomenal growth as a result of external factors such as the increasing supply chain relocation or diversification trend out of China and~~, as well as the~~ new trade agreements with ~~the~~ European Union (Khan et al., 2020). ~~The~~ Vietnam's sub-regional market was valued at over USD 60 billion in 2021, and it is expected to increase at an annual pace of over 8.71 percent from 2022 to 2027, ranking third in APAC region after Indonesia and Philippines (Bui et al., 2019). ~~Vietnam's sub-regional market had a value of around USD 60 billion in 2021, and it is forecast to grow at a rate of over 8.71% during the forecast period 2022 -2027, making it the third highest growth rate in the APAC region behind Indonesia and the Philippines (Moselhi and Khan, 2012, Bui et al., 2019). The Vietnamese~~ Vietnamese government has prioritized investments in housing projects and improving infrastructure quality, both of which impose a high demand on construction services. NGUYEN and LUU (2020) say Vietnam has imported more steel than Singapore, Malaysia, and the Philippines combined, indicating increased activity in the Vietnamese building sector.

~~Government has prioritized investments in housing projects and improving the quality of infrastructure which place heavy demand on the services of the construction sector. The heightened activities in the Vietnam's construction sector is evident in NGUYEN and LUU (2020) report that Vietnam has imported more steel than Singapore, Malaysia and Philippines combined.~~

Unfortunately, VCI continues to struggle with CT adoption and implementation. Wuni and Shen (2020) reported VCI has the slowest uptake rate of technological advances in APAC region. This paper focuses on how technology can improve the current processes in VCI. The aim is to add to the knowledge base and identify major steps necessary to transition construction operations to a more machine-dominated model as advocated by Wuni and Shen (2020). It is expected findings from this study could be relevant to other countries facing similar concerns about how to improve greater rate of adoption of CT.

~~Unfortunately, Vietnam's construction industry continues to struggle with the adoption and implementation of CT in its operations. For instance, Amuda-Yusuf et al. (2020), (Wuni and Shen, 2020) reported that the Vietnam's construction industry has the slowest uptake rate of technological advances in the APAC region. This paper focuses on how technology can play a huge role in improving the current processes in the Vietnam's construction industry. The overall aim is to contribute to the knowledge base that could inform the major steps necessary to transition construction operations to a more machine-dominated model as advocated by. It is expected that the findings from this study could be relevant to other countries facing similar concerns about how to improve greater rate of adoption of CT in the construction sector.~~

3.0 Methodology

3.1 Research Method

The descriptive survey research method was adopted for the study because ~~the~~ technique of observation was required for ~~the gathering of~~collecting empirical data which comprised opinions of survey respondents (Wuni and Shen, 2020). However, Alturki (2021) 'research onion' framework provided an appropriate, systematic and strategic approach to the overall conception, design and implementation of the research. ~~The r~~Research onion framework relevance is evident in ~~the~~ specifics about the research aim and objectives, construction knowledge domain, acceptance of value addition in the sector and research relevance, nature of empirical data, acceptable data gathering approach and analysis, scale of the research instrument used, and the interpretation and validity of the findings.

The sSix integrated but cascading research strategic steps expounded in the Alturki (2021) research onion frame comprise the research philosophy, approaches, strategies, choices, time horizons, and techniques and procedures. Relevant aspects of the six steps adopted in the context of the study areis briefly discussed as follows in figure 1 below..

Ontological philosophical position adopted in the research

The iInterpretivist/constructivist ontological philosophy was adopted to guide the research design and implementation because the research intention was focused on exploring new knowledge from the way research participants construct meaning and interpret facts. This is in contrast with the objectivist or pragmatist ontological philosophy adopted in the experimental research where meaning is deduced and inferred objectively from the observed facts independent of the observer's viewpoints (Iroha et al., 2021).

Research paradigm adopted in the study

In line with the interpretivist/ constructivist ontological philosophical position adopted in the study, the inductive research approach was followed as the guiding principle for the purposes of developing theories inductive reasoning about the factors influencing CT adoption in the Vietnam's construction industryVCI based on limited observations from secondary data and expert opinions offered at the scoping study stage. However, to mitigate the downsides of tight focus on one research approach, the deductive reasoning approach was also used to test the theories developed at the first qualitative stage of the research through survey participants' ratings of relevance of the identified constructs used to design questionnaire. This accords with opinions of authors such as Moranski and Zalbidea (2022) (Karimian et al., 2019, Moranski and Zalbidea, 2022) who identified the combination of both deductive and inductive approaches to research asfor the mixed methods research.

Epistemological research strategy adopted in the study

To align with the interpretivist ontology and the combined inductive and deductive research approaches adopted in the study, the survey-based action research was followed as the appropriate epistemological research strategyy for the study. The action research epistemology aligns with the research aim of seeking to bring about transformation in thetransform Vietnam's construction industryVCI through the promotion of adoption of CTCT adoption as a game-changer to the existingto existing traditional methods and practices. This approach drew upon by Karimian et al. (2019) recommendation that action research is the preferred strategy that suits a transformative research intent.

223 *Choice of research method*

224 Given the combined deductive and inductive research intent of developing and testing theory in
225 one research project, the mixed methods research was chosen as the most appropriate alternative
226 (Liu et al., 2017).

227 *Time horizons for the empirical data gathering*

228 In alignment with the project-based nature of the research study, the cross-sectional approach was
229 adopted requiring empirical data collection across multiple research participants within the
230 timeframe planned for the fieldwork. This approach accords with Liu and Zheng (2019)
231 observation that majority of the survey-based research projects conducted in the construction
232 industry follows a cross-sectional approach due to the shifting nature and locations of construction
233 projects, teams and processes.

Ontological philosophical position adopted in the research	Interpretivist/constructivist ontological philosophy was adopted to guide research design and implementation because intention was focused on exploring new knowledge from the way research participants construct meaning and interpret facts. This is in contrast with objectivist or pragmatist ontological philosophy adopted in experimental research where meaning is deduced and inferred objectively from observed facts independent of observer's viewpoints (Iroha et al., 2021).
Research paradigm adopted in the study	In line with interpretivist/constructivist ontological philosophical position adopted in study, inductive research approach was followed as the guiding principle for purposes of developing theories inductive reasoning about factors influencing CT adoption in VCI based on limited observations from secondary data and expert opinions offered at scoping study stage. However, to mitigate downsides of tight focus on one research approach, deductive reasoning approach was used to test theories developed at first qualitative stage of research through survey participants' ratings of relevance of identified constructs used to design questionnaire. This accords with opinions of authors such as Moranski and Zalbidea (2022) who identified combination of both deductive and inductive approaches for the mixed methods research.
Epistemological research strategy adopted in the study	To align with interpretivist ontology and combined inductive and deductive research approaches, survey-based action research was followed as appropriate epistemological research strategy. The action research epistemology aligns with the research aim of seeking to transform VCI through the promotion CT adoption as a game-changer to existing traditional methods and practices. This approach drew upon by Karimian et al. (2019) recommendation that action research is the preferred strategy suits a transformative research intent.
Choice of research method	Given the combined deductive and inductive research intent of developing and testing theory in one research project, the mixed methods research was chosen as the most appropriate alternative (Liu et al., 2017).
Time horizons for the empirical data gathering	In alignment with project-based nature of research study, the cross-sectional approach was adopted requiring empirical data collection across multiple research participants within timeframe planned for fieldwork. This approach accords with Liu and Zheng (2019) observation majority of the survey-based research projects conducted in construction industry follows a cross-sectional approach due to shifting nature and locations of construction projects, teams and processes. (Alwanas et al., 2019)
Research technique and procedure adopted in the study	A two-stage descriptive survey research method was adopted in alignment with research aim and objectives. First, a comprehensive literature review 215 related articles were conducted to obtain construct for second stage questionnaire survey. Using constructs gleaned from previous studies and additional insights provided by experts in the construction industry, a questionnaire was designed and administered to experienced CM in VCI with a view to eliciting responses to questions about extent of adoption of CT tools, barriers, drivers, and most popular CT tools. Descriptive statistics were used to summarize characteristics of interest about the empirical dataset and SPSS-based inferential statistics to estimate the means, frequency counts and variance, as well as test hypotheses that informed the drawing of conclusions in relation to research objectives

Figure 1 Six integrated Research Onion Steps

~~*Research technique and procedure adopted in the study*~~

~~A two-stage descriptive survey research method was adopted in alignment with the research aim and objectives. First, a comprehensive literature review 215 related articles were conducted to~~

~~obtain construct for the second stage questionnaire survey. Using the constructs gleaned from previous studies and additional insights provided by experts in the construction industry, a questionnaire was designed and administered to experienced construction project managers~~CM ~~in the Vietnam's construction industry~~VCI ~~with a view to eliciting responses to questions about the extent of adoption of CT tools, barriers, drivers, and the most popular CT tools. Descriptive statistics were used to summarize the characteristics of interest about the empirical dataset, while~~ and ~~SPSS-based inferential statistics were used to estimate the means, frequency counts and variance, as well as test hypotheses that informed the drawing of conclusions in relation to the research objectives~~

This study like every other research has its set of limitations. ~~The study~~It was based on ~~the~~ perspectives of experienced ~~project managers~~CM~~–~~ who have firsthand experience in ~~the~~ implementation, adoption, and management of ~~construction technologies (CT)~~CT in their respective projects and firms. ~~Secondly, t~~The study was limited to project management related CT that have a direct impact on the 10 knowledge areas that comprise the Project Management Body of Knowledge (PMBOK, 2018), namely, cost, quality, schedule, resource, safety, risk, human resource, communication, contract, and project setup including stakeholder management. The scope of the software referenced in this study was limited to what was popularly used in ~~the Vietnam's construction industry~~VCI within the delineated timeframe for ~~the~~ fieldwork. The study timeline is critical and research articles from 2005 – 2022 were taken into consideration. If same keywords are used later a different result will be achieved due to research timeline difference.

Given ~~that~~ this study is the first in ~~the Vietnam's construction industry~~VCI, it is expected ~~that the~~ findings of this study would be of great value to researchers, learners, practitioners and policy-makers and other stakeholders who may be interested in finding new ways to increase ~~the~~ CT adoption and implementation ~~of CT in the construction sector and construction projects~~. Despite the identified limitations, the findings could provide the starting point for further research in ~~the~~ region and inform wider debate on the issues going forward.

3.2 Secondary and primary data gathering stages

The first phase of this research involved a systematic review of cognate and contemporary studies on the topic. ~~Elsevier's~~ Scopus was the only scientific database from where ~~the~~ articles were reviewed mainly due to ensuring quality of data and more accurate results.

Keywords used to search for relevant and current articles comprised "Adoption", "Construction", "~~challenge~~Challenge", "Factors", "~~productivity~~Productivity" AND Technology"

A total of 2,140 articles were found in relation to ~~the~~ research. After a thorough review of each article, only 215 were found relevant to ~~the~~ current research. Advanced tools from Bluebeam were used to review ~~the~~ article ~~content of the articles to~~content and ensure a quicker review of important information. The following ~~information~~ was extracted from the selected articles:

(1) Administrative information such as name of authors, affiliation details, location of study and ~~the~~ total number of identified factors
(2) Data analysis to understand ~~the~~ major objectives, ~~and~~ key findings and ~~the~~ impact to the body of knowledge
(3) Data collection method to understand ~~the~~ target of research, how it was successful in ~~the~~ method used and ~~the~~ major research limitations ~~to the research~~

~~The m~~Major findings have been inserted in Tables 1 and 2. Table 1 identifies major CT tools. Table 2 lists ~~the~~ major barriers to CT adoption identified in previous studies. Findings based on geographic regions were ~~also~~ collated.

~~The s~~Second phase of ~~the~~ research focused on developing ~~the~~ questionnaire as ~~the~~ research instrument for primary data gathering with VCI ~~the Vietnams' construction industry~~ as ~~the~~ delineated study region. To explore ~~the~~ relevance and relative importance of ~~the~~ constructs identified during the first phase a list of questions was compiled to elicit rating responses from experienced ~~project managers~~CM registered with ~~the~~ Vietnam's chapter of the Asian Pacific Federation of Project Management.

3.3 Empirical data analytical approach

~~Descriptive statistics were used to summarize the characteristics of interest about the empirical dataset, while SPSS-based inferential statistics were used to estimate the means, frequency counts and variance, as well as test hypotheses that informed the drawing of conclusions in relation to the research objectives.~~ This approach drew upon ~~the~~ recommendations of Iroha et al. (2021) given ~~the~~ nature research objectives, ~~the~~ distribution-free nature of ~~the~~ empirical data and ~~the~~ ordinal scale of measurement employed in ~~the~~ survey research instrument. The following comprise the key parameters used in ~~the~~ empirical data analyses.

The importance index (II) was used to compute combined rating responses received ~~from the project managers~~from CM. Effect size was determined by dividing ~~the~~ difference between ~~the~~ sample statistics by ~~the~~ standard error. ~~The q~~Quotient was subsequently used to determine relative levels of importance of ~~the~~ identified major factors. ~~The t~~Test range was determined to be higher than 171 (assuming 5000 ~~project managers~~CM and a margin of error of ±5%).

~~A~~ Cronbach's ~~alpha, as a~~alpha, a reliability coefficient, was calculated to ensure ~~that the~~ survey was internally reliable and consistent. ~~The a~~Analytical approach drew from similar approach adopted by Murat et al. (2020) in evaluating human efficiency drivers for construction labor productivity. Equations 1 and 2 show ~~the~~ expressions for deriving ~~the~~ Cronbach alpha (Zhao et al., 2022) and Importance Index (Karimian et al., 2019).

Using ~~the~~ Cronbach alpha statistic, ~~the~~ degree to which responses to survey questions were correlated were analyzed. ~~The r~~Result was used to estimate ~~the~~ percentage of variance that is systematic or consistent across a set of responses. An index value of 0.7 is acceptable, while a value of 0.8 or greater indicates good internal consistency (Zhao et al., 2022). Cronbach's alpha coefficient is calculated using Equation 1

$$\alpha = \frac{N.\bar{c}}{\bar{v} + (N-1).\bar{c}} \qquad (1)$$

where,

~~Where:~~

N = the number of factors being ~~rated;~~rated.

$\bar{c}$ = the mean covariance between ~~factor~~factors ~~sets;~~sets.

$\bar{v}$ = the mean variance

~~The c~~Coefficient was calculated using the SPSS version 24 software. The coefficient of determination calculated using SPSS version 24 software which was found to be 0.86.

From zero to one, ~~the~~ importance index (II) indicates how significant a particular attribute is in comparison to other attributes (Karimian et al., 2019). Equation 2 provides ~~the~~ expression for evaluating the II of each factor rated by ~~the~~ respondents within a set of variables.

$$Importance\ Index = \frac{3n_1 + 2n_2 + 1n_3}{3(n_1 + n_2 + n_3)} \qquad (2)$$

where,

n_1 = High importance

n_2 = Moderate importance

n_3 = Low importance

There is no requirement for ~~the~~ data distribution to be normal or homogeneous in order to use Spearman's rank correlation coefficient (Zhao et al., 2022). ~~The~~ Spearman's correlation coefficient is used to ascertain whether two different variables are associated with each other, as distinct from being linearly correlated. Based on Spearman's correlation theory, a variable's score must be monotonically related to another variable for correlation significance, and ~~the~~ two variables must be measured on ~~the~~ ordinal scale. ~~The c~~Correlation among the numerous categories of respondents in this study was evaluated using ~~the~~ Spearman's coefficient, expressed in Equation 3.

$$r = 1 - [\frac{6\sum d^2}{n^3 - n}] \quad (3)$$

where,

~~Where,~~

r = Spearman rank correlation coefficient between two factors;
d = ~~the~~ difference between ranks assigned to factors;
n = ~~the~~ number of pairs of rank (equals the number of attributes, which is 40 in this research)
~~The c~~Correlation coefficient ranges from -1, which means a perfect negative relationship (disagreement), to +1, which means a perfect positive relationship (agreement).

Based on ~~the~~ analysis of results, limitations were identified, and data driven solutions were prepared. Future studies related to adoption of ~~construction technology~~CT were recommended.

4.~~-~~0 ~~DATA PRESENTATION AND DISCUSSION OF RESULTS~~Data Presentation and Discussion of Results

4.1 Technology Tools and Users

To understand the current tools in use in ~~the~~ current construction projects, the authors chose to seek the assistance of the CT department in ~~the~~ construction firms through online questionnaire. Through their assistance, a table was created to list down all the technologies currently in adoption and ~~the~~ numbers of users applying the tools on a regular basis. The tools with ~~the~~ highest number of users were used ~~in the questionnaires~~for survey and basis of discussion for ~~the~~ article.

~~The p~~Parameters for ~~the~~ selection of tools is listed below:

a. ~~Only the to~~Tools which had a direct interaction with ongoing construction projects were listed.
b. ~~Only the t~~Tools which were used in the construction project management were listed. In construction cycle and terminology, this meant ~~the~~ Design, Procurement, Construction and Closing Phase related tools.
c. ~~The l~~List was created from Vietnam's ~~the~~ perspective ~~of Vietnam~~. ~~The a~~Authors ~~finally~~ chose ~~the~~ top tools with ~~the~~ highest number of users for ~~the~~ questionnaires and discussion in ~~the~~ research article.

Table 1 List of construction technologies

CT Software	**Software type**

Aurigo, Build, Coconstruct, Corecon, Dropbox, Kitework, Microsoft Office, Monday Construction, Procore Technologies, Viewpoint and Workflowmax	Document control
AutoCAD, Bluebeam	Design
Bridgit, Fieldwire	Workforce
Building Connected	Tender
Microsoft Project, Oracle Primavera	Schedule
Sage 100 Contractor	Accounting
Smartsheet	Tasks

~~**CT Software**~~	~~**Software type**~~
~~**Aurigo**~~	~~Document control~~
~~**AutoCAD Tools**~~	~~Design~~
~~**Bluebeam**~~	~~Design~~
~~**Bridgit**~~	~~Workforce~~
~~**Building Connected**~~	~~Tender~~
~~**Coconstruct**~~	~~Document control~~
~~**Corecon**~~	~~Document control~~
~~**Dropbox**~~	~~Document control~~
~~**Fieldwire**~~	~~Workforce~~
~~**Kitework**~~	~~Document control~~
~~**Microsoft Office**~~	~~Document control, Schedule~~

~~**Monday construction**~~	~~Document control~~
~~**Oracle Primavera**~~	~~Schedule~~
~~**Plangrid**~~	~~Document control~~
~~**Procore Technologies**~~	~~Document control~~
~~**Sage 100 Contractor**~~	~~Accounting~~
~~**Smartsheet**~~	~~Tasks~~
~~**Viewpoint**~~	~~Document control~~
~~**Workflowmax**~~	~~Document control~~

4.2 Findings from Previous Studies

A deep dive into the literature resulted in the authors to come up with the following findings:

It can be noted from ~~the~~ figure ~~1~~2 ~~that~~ most ~~of the~~ studies have been completed in these countries: Nigeria (7 studies), Malaysia (6 studies), Australia (5 studies), USA (5 studies) and India (4 studies). USA and Australia are developed countries and India, Malaysia and Nigeria (most construction work in these countries is done by ~~labour~~labor since they are developing countries). Research gaps exist in South America and Europe and Oceania, as there have been no studies conducted. Further study of the South American continent can provide ~~construction project managers~~CM with guidance on how to focus their attention, act upon, and control the critical factors ~~that~~ influence adoption. South American studies can ~~also~~ provide a broader and deeper perspective on motivational factors affecting performance.

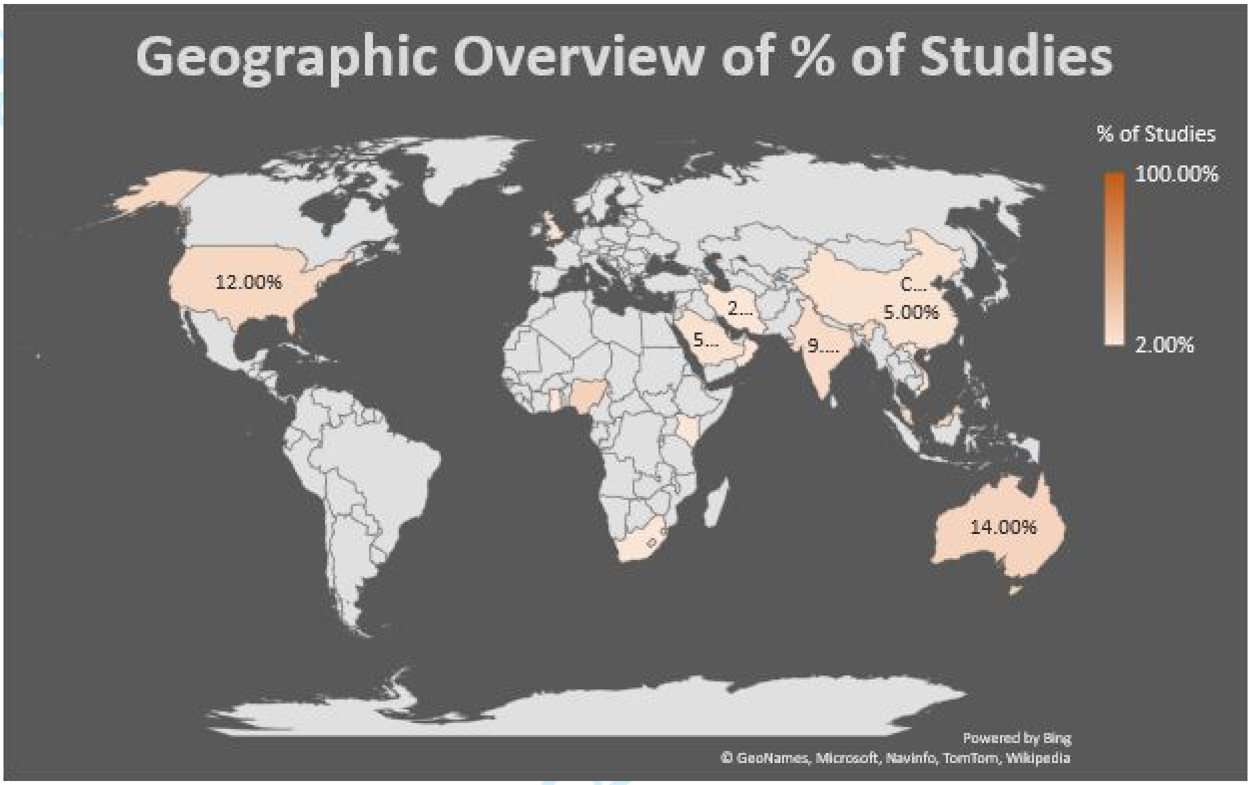


Figure ~~1~~2: Geographic Overview of % of Studies

There are many challenges faced in adoption of technologies as discussed by ~~the~~ past researchers ~~in the past~~. Below is a summary of ~~the~~ top challenges faced for CT adoption ~~of construction technologies~~ in respective articles. Researchers rank various factors differently and these rankings are presented. In the table, only factors ~~that~~ ranked among the top 5 are shown. A 1 represents the most important factor ~~(among the five most important factors)~~ and a 5 represents the least important (among the five most important factors). According to researchers, ~~the~~ following conclusion has been reached most frequently: (1) High set up cost (2) Lack of available information on technology reliability, implementation, and benefits (3) Lack of support from top management (4) Lack of human expertise, capability, client knowledge and training and (5) Lack of institutional policies and guidelines.

~~The f~~Factors were grouped into seven different categories. ~~The c~~Categories were adopted from Chan et al. (2018) research article titled “Critical barriers to green building technologies adoption in developing countries: The case of Ghana”. The seven categories are: G1: Regime-associated factors; G2: Individual-associated factors; G3: Data-associated factors; G4: Market-associated factors; G5: Finance-associated factors; G6: Business associated factors and G7: IT associated factors. This category was ~~also~~ used by other respective researchers in their studies (Qin et al., 2020) ~~(Attarzadeh et al., 2015, Liu et al., 2010, Muthusamy and Chew, 2020, Vidalakis et al.,~~

~~2020, Qin et al., 2020)~~. ~~The t~~Table 2 reveals ~~the~~ following factors as most influential when ~~the~~ factors are grouped into categories. Only ~~the~~ topmost factor is highlighted. For G7 (Software capability does not match project requirements), G6 (Ease of maintenance, productivity), G5 (High set up cost), G4 (Importance of software / Internal needs), G3 (Lack of available information on technology reliability, implementation, and benefits), G2 (Lack of human expertise, capability, client knowledge and training) and G1 (Lack of institutional policies and guidelines).

Table 2 Influential Factors Identified in Literature Review

G	**Factors**	**Rank by Researchers**	**∑**
7a	Software capability does not match project requirements	(1) 33, 6, (2) 37, (3) 23, 22, (4) 17, 38, (5) 39, 8	**9**
6a	Ease of maintenance	(5) 1	**1**
6b	Productivity did not improve	(3) 2	**1**
5a	High set up cost	(1) 43, 13, 34, 2, 36, 24, 12, (2) 6, 8, (3) 30, 27, (4) 41	**12**
5b	Risks in implementation	(1) 19, 20, (2) 16, (4) 14, 1, (5) 18	**6**
5c	Project complexity did not allow for new software to be implemented	(1)16, 17, (2) 2, 18, 12	**5**
5d	Long lead time required for full-scale implementation	(1) 7, (2) 11, (3) 12, (4) 13	**4**
5e	Legal and contractual constraints on adopting technology	(2) 4	**1**
5f	Lack of tax related benefits, return on	(1) 21, 30, (2) 40, 9, (3) 15, 17, (5) 41, 42, 24, 3	**10**

G	Factors	Rank by Researchers	∑
	investment not clear		
5g	High training and running costs	(1) 15, 42, 27, (2) 34, 43, 23, 13, (3) 4, (4) 12, 6 (5) 36	11
4a	Importance of software not clear / internal staff needs do not match software requirements	(1) 10, (3)14, (4) 15, 3	4
4b	Business agility / expansion	(2) 3, (3) 9	2
3a	Lack of available information on technology reliability, implementation, and benefits	(1) 8, 41, 25, 40, 39, (2) 5, 35, 33, 28, (3) 26, 18, 42, 16, 11, 32, 38, (4) 34, 30, 21	19
3b	Lack of knowledge and understanding of use	(2) 24, 25, (4) 26, 19, 27, 11, (5) 28, 29	8
3c	Lack of understanding	(1) 22, 1, (2) 36, 32, (3) 28, 13, 31, (4) 24	8
3d	Lack of funds during budget planning for technological advances and implementation~~Drawings and specifications do not require software~~	(1) 5, (2) 10	2
3e	Late implementation of software in project planning	(5) 5, 6	2

G	Factors	Rank by Researchers	∑
3f	Lack of experts required for technological change and insufficient skills in the industry were identifiedImprovement in project quality did not identify technology as a requirement	(3) 3	1
2a	Lack of human expertise, capability, client knowledge and training	(1) 35, 11, 14, (2) 29, 21, 19, 31, 7, 26, (3) 34, 24, 10, 43, 33, 41, 25, 40, 20, 36, (4) 42, 39, 28, (5) 13, 27, 4, 9	26
2b	Lack of support from top management	(1) 38, 9, 31, 26, 37, (2) 14, 42, 15, (3) 6, 8, 39, 1, 5, (4) 35, 20, 10	16
2c	Resistance to change	(1) 18, 4, (2) 20, (3) 7, (5) 30, 31, 23, 10, 12	9
2d	Company culture on adoption of technologies and innovation strategies	(2) 1, (3) 21, (4) 9, 22, 23, (5) 2, 15	7
2e	Staffing shortage on adoption of technology requires new roles/responsibilities	(4) 7, 8	2
1a	Lack of institutional policies and guidelines	(1) 29, 32, 28, (2) 41, 39, (3) 35, 19, (4) 18, 4, 36, 16, (5) 26, 33	13

G	Factors	Rank by Researchers	∑
1b	Lack of government/client mandate	(1) 23, (2) 30, (4) 31, 32, 2, 33, (5) 20, 34, 35	8

Hong et al. (2016) – 1, Pan et al. (2020) – 2, Nguyen et al. (2015) – 3, Abubakar et al. (2014) – 4, Wuni and Shen (2020) – 5, Attarzadeh et al. (2015) – 6, Zahrizan et al. (2013) – 7, Liu et al. (2010) – 8, Shehzad et al. (2019) – 9, Sargent et al. (2012) – 10, NGUYEN and LUU (2020) – 11, Borhani (2016) – 12, Ahuja et al. (2020) – 13, Fernandes et al. (2006) – 14, Talukder (2012) – 15, Saleh and Alalouch (2020) – 16, Ahuja et al. (2010) – 17, Osunsanmi et al. (2020) – 18, Thomas and Abraham (2020) – 19, Saka and Chan (2020) – 20, Usman and Gidado (2015) – 21, Foroozanfar et al. (2017) – 22, Peansupap and Walker (2005) – 23, Chan et al. (2018) – 24, Noghabaei et al. (2020) – 25, Babatunde et al. (2020) – 26, Vidalakis et al. (2020) – 27, Amuda-Yusuf et al. (2020) – 28, (Ahuja et al., 2009) – 29, Muthusamy and Chew (2020) – 30, Al-Hammadi and Tian (2020) – 31, Omamo (2012) – 32, Lam et al. (2010) – 33, Nnaji and Karakhan (2020) – 34, Hamma-adama et al. (2020) – 35, Zaini et al. (2020) – 36, Ding et al. (2015) – 37, Doumbouya et al. (2016) – 38, Almashjary et al. (2020) – 39, Olaniyan et al. (2020) – 40, Qin et al. (2020) – 41, Abbasnejad et al. (2020) – 42 Akmam Syed Zakaria and Amtered El-Abidi (2020)~~, Akmam Syed Zakaria and Amtered El-Abidi (2020)~~ – 43. Foroozanfar et al. (2017) –44, Ahuja et al. (2009) – 45, Sepasgozar and Davis (2018) – 46, Momade et al. (2021b)~~Momade and Hainin (2018)~~ – 47

~~G~~	~~Factors~~	~~Rank by Researchers~~	~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~∑~~
~~7~~	~~Software capability does not match project requirements~~	~~(1) Lam et al. (2010), (1) Attarzadeh et al. (2015), (2) Ding et al. (2015), (3) Peansupap and Walker (2005), (3) Foroozanfar et al. (2017) (4) Ahuja et al. (2010), (4) Doumbouya et al. (2016), (5) Almashjary et al. (2020), (5) Liu et al. (2010)~~	~~2~~	~~1~~	~~2~~	~~2~~	~~2~~	~~9~~
~~6~~	~~Ease of maintenance~~	~~(5) Hong et al. (2016)~~	~~0~~	~~0~~	~~0~~	~~0~~	~~1~~	~~1~~
~~6~~	~~Productivity did not improve~~	~~(3) Pan et al. (2020)~~	~~0~~	~~0~~	~~1~~	~~0~~	~~0~~	~~1~~
~~5~~	~~High set up cost~~	~~(1) Akmam Syed Zakaria and Amtered El-Abidi (2020), (1) Ahuja et al. (2020), (1) Nnaji and Karakhan (2020), (1) Pan et al. (2020), (1) Zaini et al. (2020), (1) Chan et al. (2018), (1) Borhani (2016), (2) Attarzadeh et al. (2015), (2) Liu et al. (2010) (3) Muthusamy and Chew (2020), (3) Vidalakis et al. (2020), (4) Qin et al. (2020)~~	~~7~~	~~2~~	~~2~~	~~1~~	~~0~~	~~12~~
~~5~~	~~Risks in implementation~~	~~(1) Thomas and Abraham (2020), (1) Saka and Chan (2020), (2) Saleh and Alalouch (2020), (4) Fernandes et al. (2006), (4)~~	~~2~~	~~1~~	~~0~~	~~2~~	~~1~~	~~6~~

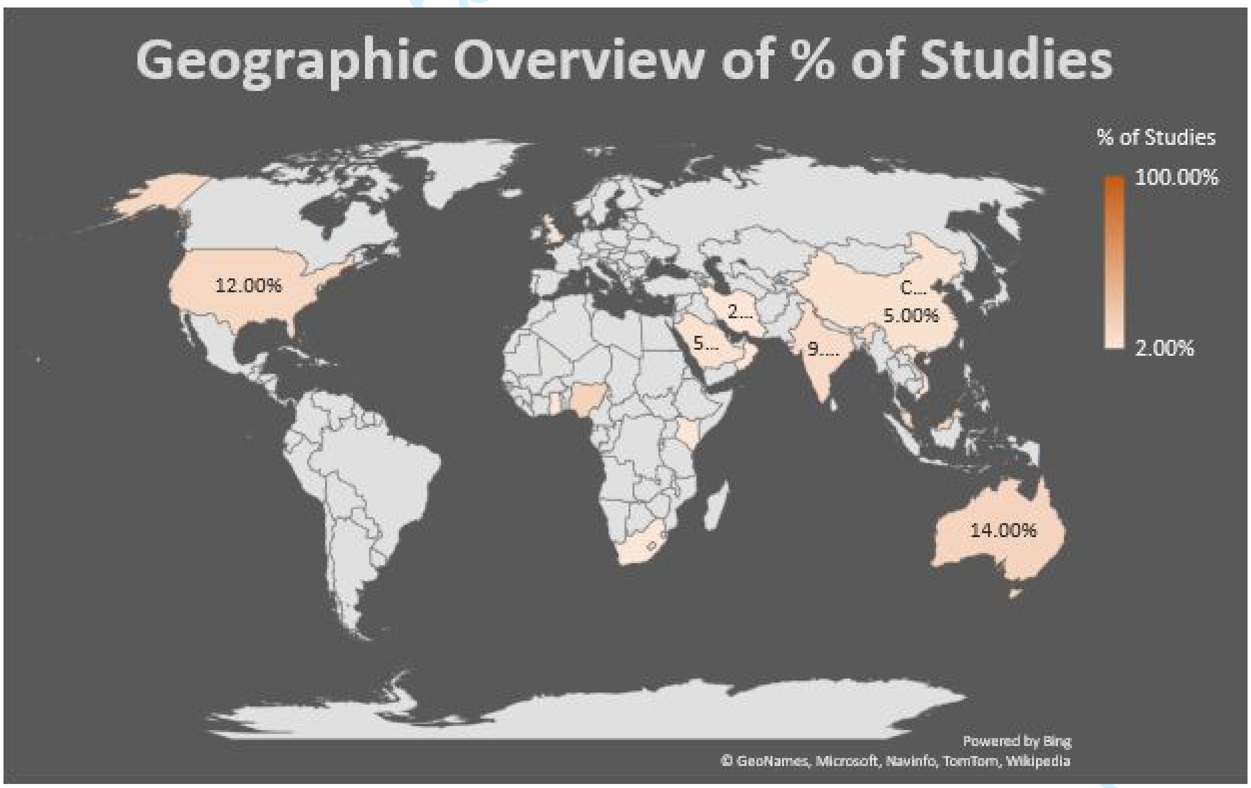
G	Factors	Rank by Researchers	1	2	3	4	5	∑
		Hong et al. (2016) (5) Osunsanmi et al. (2020)						
5	Project complexity did not allow for new software to be implemented	(1) Saleh and Alalouch (2020), (1) Ahuja et al. (2010), (2) Pan et al. (2020), (2) Osunsanmi et al. (2020), (2) Borhani (2016)	2	3	0	0	0	**5**
5	Long lead time required for full-scale implementation	(1) Zahrizan et al. (2013), (2) NGUYEN and LUU (2020), (3) Borhani (2016), (4) Ahuja et al. (2020)	1	1	1	1	0	**4**
5	Legal and contractual constraints on adopting technology	(2) Abubakar et al. (2014)	0	1	0	0	0	**1**
5	Lack of tax related benefits, return on investment not clear	(1) Usman and Gidado (2015), (1) Muthusamy and Chew (2020), (2) Olaniyan et al. (2020), (2) Shehzad et al. (2019), (3) Talukder (2012), (3) Ahuja et al. (2010), (5) Qin et al. (2020), (5) Abbasnejad et al. (2020), (5) Chan et al. (2018), (5) Nguyen et al. (2015)	2	2	2	0	4	**10**
5	High training and running costs	(1) Talukder (2012), (1) Abbasnejad et al. (2020), (1) Vidalakis et al. (2020), (2) Nnaji and Karakhan (2020), (2) Akmam Syed Zakaria and Amtered El-Abidi (2020), (2) Peansupap and Walker (2005), (2) Ahuja et al. (2020), (3) Abubakar et al. (2014), (4) Borhani (2016), (4) Attarzadeh et al. (2015) (5) Zaini et al. (2020)	3	4	1	2	1	**11**
4	Importance of software not clear / internal staff needs do not match software requirements	(1) Sargent et al. (2012), (3) Fernandes et al. (2006), (4) Talukder (2012), (4) Nguyen et al. (2015)	1	0	1	2	0	**4**
4	Business agility / expansion	(2) Nguyen et al. (2015), (3) Shehzad et al. (2019)	0	1	1	0	0	**2**
3	Lack of available information on technology reliability, implementation, and benefits	(1) Liu et al. (2010), (1) Qin et al. (2020), (1) Noghabaei et al. (2020), (1) Olaniyan et al. (2020), (1) Almashjary et al. (2020), (2) Wuni and Shen (2020), (2) Hamma-adama et al. (2020), (2) Lam et al. (2010), (2) Amuda-Yusuf et al. (2020), (3) Babatunde et al. (2020), (3) Osunsanmi et al. (2020), (3) Abbasnejad et al. (2020), (3) Saleh and	5	4	7	3	0	**19**

G	Factors	Rank by Researchers	1	2	3	4	5	∑
		Alalouch (2020), (3) NGUYEN and LUU (2020), (3) Omamo (2012), (3) Doumbouya et al. (2016) (4) Nnaji and Karakhan (2020), (4) Muthusamy and Chew (2020), (4) Usman and Gidado (2015)						
3	Lack of knowledge and understanding of use	(2) Chan et al. (2018) (2) Noghabaei et al. (2020), (4) Babatunde et al. (2020), (4) Thomas and Abraham (2020), (4) Vidalakis et al. (2020), (4) NGUYEN and LUU (2020), (5) Amuda-Yusuf et al. (2020), (5) (Ahuja et al., 2009)	0	2	0	4	2	**8**
3	Lack of understanding	(1) Foroozanfar et al. (2017) (1) Hong et al. (2016), (2) Zaini et al. (2020), (2) Omamo (2012), (3) Amuda-Yusuf et al. (2020), (3) Ahuja et al. (2020), (3) Al-Hammadi and Tian (2020), (4) Chan et al. (2018)	2	2	3	1	0	**8**
3	Drawings and specifications do not require software	(1) Wuni and Shen (2020), (2) Sargent et al. (2012)	1	1	0	0	0	**2**
3	Late implementation of software in project planning	(5) Wuni and Shen (2020), (5) Attarzadeh et al. (2015)	0	0	0	0	2	**2**
3	Improvement in project quality did not identify technology as a requirement	(3) Nguyen et al. (2015)	0	0	1	0	0	**1**
2	Lack of human expertise, capability, client knowledge and training	(1) Hamma-adama et al. (2020), (1) NGUYEN and LUU (2020), (1) Fernandes et al. (2006), (2) (Ahuja et al., 2009), (2) Usman and Gidado (2015), (2) Thomas and Abraham (2020), (2) Al-Hammadi and Tian (2020), (2) Zahrizan et al. (2013) (2) Babatunde et al. (2020), (3) Nnaji and Karakhan (2020), (3) Chan et al. (2018), (3) Sargent et al. (2012), (3) Akmam Syed Zakaria and Amtered El-Abidi (2020), (3) Lam et al. (2010), (3) Qin et al. (2020), (3) Noghabaei et al. (2020), (3) Olaniyan et al. (2020), (3) Saka and Chan (2020), (3) Zaini et al. (2020), (4) Abbasnejad et al. (2020), (4) Almashjary et al. (2020), (4) Amuda-Yusuf et al. (2020), (5) Ahuja et al. (2020),	3	6	10	3	4	**26**

G	Factors	Rank by Researchers	1	2	3	4	5	∑
		(5) Vidalakis et al. (2020), (5) Abubakar et al. (2014), (5) Shehzad et al. (2019)						
2	Lack of support from top management	(1) Doumbouya et al. (2016) (1) Shehzad et al. (2019), (1) Al-Hammadi and Tian (2020), (1) Babatunde et al. (2020), (1) Ding et al. (2015), (2) Fernandes et al. (2006), (2) Abbasnejad et al. (2020), (2) Talukder (2012), (3) Attarzadeh et al. (2015), (3) Liu et al. (2010), (3) Almashjary et al. (2020), (3) Hong et al. (2016), (3) Wuni and Shen (2020), (4) Hamma-adama et al. (2020), (4) Saka and Chan (2020), (4) Sargent et al. (2012)	5	3	5	3	0	**16**
2	Resistance to change	(1) Osunsanmi et al. (2020), (1) Abubakar et al. (2014), (2) Saka and Chan (2020), (3) Zahrizan et al. (2013), (5) Muthusamy and Chew (2020), (5) Al-Hammadi and Tian (2020), (5) Peansupap and Walker (2005), (5) Sargent et al. (2012), (5) Borhani (2016)	2	1	1	0	5	**9**
2	Company culture on adoption of technologies and innovation strategies	(2) Hong et al. (2016), (3) Usman and Gidado (2015), (4) Shehzad et al. (2019), (4) Foroozanfar et al. (2017) (4) Peansupap and Walker (2005), (5) Pan et al. (2020), (5) Talukder (2012)	0	1	1	3	2	**7**
2	Staffing shortage on adoption of technology requires new roles/responsibilities	(4) Zahrizan et al. (2013), (4) Liu et al. (2010)	0	0	0	2	0	**2**
1	Lack of institutional policies and guidelines	(1) (Ahuja et al., 2009), (1) Omamo (2012) (1) Amuda-Yusuf et al. (2020), (2) Qin et al. (2020), (2) Almashjary et al. (2020), (3) Hamma-adama et al. (2020), (3) Thomas and Abraham (2020), (4) Osunsanmi et al. (2020), (4) Abubakar et al. (2014), (4) Zaini et al. (2020), (4) Saleh and Alalouch (2020), (5) Babatunde et al. (2020), (5) Lam et al. (2010)	3	2	2	4	2	**13**
1	Lack of government/client mandate	(1) Peansupap and Walker (2005), (2) Muthusamy and Chew (2020), (4) Al-Hammadi and Tian (2020), (4) Omamo (2012), (4) Pan et al. (2020), (4) Lam et al. (2010), (5) Saka and Chan (2020), (5) Nnaji	1	1	0	4	2	**8**

~~G~~	~~Factors~~	~~Rank by Researchers~~	~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~∑~~
		~~and Karakhan (2020), (5) Hamma-adama et al. (2020)~~						

~~It can be noted from the figure 1 that most of the studies have been completed in these countries: Nigeria (7 studies), Malaysia (6 studies), Australia (5 studies), USA (5 studies) and India (4 studies). USA and Australia are developed countries and India, Malaysia and Nigeria (most construction work in these countries is done by labour since they are developing countries). Research gaps exist in South America and Europe and Oceania, as there have been no studies conducted. Further study of the South American continent can provide construction project managersCM with guidance on how to focus their attention, act upon, and control the critical factors that influence adoption. South American studies can also provide a broader and deeper perspective on motivational factors affecting performance.~~



~~Figure 1: Geographic Overview of % of Studies~~

~~This study indicates that the c~~Construction industry requires new thinking. A more harmonious working environment can be created by adopting strategies to ~~that~~ improve ~~the~~ level of integration. ~~The f~~Following are some ~~of the~~ recommendations summarized by experts in ~~the~~ past for stronger performance of technology in ~~the~~ building industry. (1) Synergy of all building players to create an implementation strategy ~~(Dulaimi et al., 2002, Chan et al., 2018, Kamar et al., 2014, Phang et al., 2020, Ma et al., 2019)~~, (2) Government support and initiative ~~(Dulaimi et al., 2002, Mohammad et al., 2018, Ahuja et al., 2020, Waziri et al., 2017, Sexton and Barrett, 2004, Afolabi et al., 2019)~~, (3) Implementation of adoption model / infrastructure / culture ~~(Borhani, 2016, Fernandes et al., 2006, Phang et al., 2020, Waziri et al., 2017)~~, (4) Study on organizations where adoption rate is higher to understand emerging trends ~~(Chan et al., 2017)~~ (5) Comparison of results with other industrial sectors ~~(Fernandes et al., 2006)~~. (6) Use of more participants during research for better validation of findings ~~(Hong et al., 2016, Chan et al., 2017, Gao et al., 2018)~~, and (7) Absence of trust and awareness of technology ~~(Benbasat and Wang, 2005, Momade and Hainin, 2019, Afolabi et al., 2019)~~. Major limitations in previous studies have been discussed by the Authors earlier. Hence, the research goes a step further in identifying ~~the~~ major barriers in Vietnam.

4.3 Identification of factors at ~~Vietnam's construction industry~~VCI

~~The b~~Basic measure of survey data is ~~the~~ descriptive statistic. ~~The p~~Purpose of this study was to identify ~~the~~ influential factors in implementation of technology in ~~construction in Vietnam~~VCI. A total of 226 valid questionnaires were received ~~for the study~~. ~~The d~~Demographic of respondents is shown in Table 3~~. It can be noted from the table~~ where ~~that~~ most ~~of the~~ respondents were male (87.6%) compared to female (12.4%). That is a given since most of ~~the~~ construction work is dominated by males. ~~It can also be noted that m~~Most ~~of the~~ respondents were educated (94.7% of respondents had a Bachelor's, Master, or a Doctorate). In terms of work experience, most ~~of the~~ respondents had 1-10 years (newer generation ~~has~~ have more hands-on experience with technology) of proven experience (resumes were required and verification was completed with ~~the~~ human resource department in respective company) in ~~the~~ construction industry. Majority of ~~the~~ respondents worked for a general contractor or a consultancy firm. The survey covered a wide variety of construction related roles which allowed for a comprehensive finding to be made.

~~Respondents' demographics (N = 226)~~

Table 3 Respondents~~'~~ demographicss

Variables	Categories	Frequency	Percentage
Gender	Male	198	87.6%
	Female	28	12.4%
Education level (degree)	Diploma	12	5.3%
	Bachelor's ~~degree~~	161	71.2%
	Master's ~~degree~~	47	20.8%
	Doctorate~~'s degree~~	6	2.7%
Work experience (years)	1-5	142	62.8%
	6-10	49	21.7%
	11-15	27	11.9%
	16-20	5	2.2%

	>20	3	1.3%
Organizational Involvement	Client	20	8.8%
	General Contractor	71	31.4%
	Sub-contractor	21	9.3%
	Supervision	43	19.0%
	Consultant	71	31.4%
Role in project	~~Project~~ Construction manager	27	11.9%
	Site manager	33	14.6%
	Site supervisor	18	8.0%
	Site engineer	35	15.5%
	Designer	46	20.4%
	Architect	38	16.8%
	Estimator	24	10.6%
	Company manager	5	2.2%

The next section in ~~the~~ ~~questionnaire~~ survey was to understand ~~the~~ extent ~~of use of~~ CT tools application in AEC industry. ~~Therefore, the r~~Respondents ~~were asked to~~ ranked from 1 to 3 (1 being low ~~importance~~ and 3 being high importance) on ~~the~~ CT tools used ~~in their respective construction projects~~. As can be noted from Table 4, most ~~of the~~ respondents ranked Autodesk tools as highly important giving it rank ~~1 in total~~1. Microsoft office tools was ranked 2, and referring to the mean, ~~it can be noted~~ it was very close to Autodesk tools. Given ~~that~~ Vietnam is a developing country and most of the construction projects work on a very low-profit margin, the adoption of CT tools is limited. ~~On the other hand,~~ CT tools are improving project ~~the level of~~ productivity and ~~making the projects more~~ efficiency~~t~~. Although these improvements add value to ~~the~~ project, it is difficult to put a financial value to ~~the~~ CT adoption ~~of CT~~. In comparison, a study commissioned by Ezeokoli et al. (2016) revealed 54% of developing country respondents utilized 2D CAD exclusively, while 12% utilized 3D CAD exclusively, and 20% (2D) and 14% ~~respectively for 2D and~~ 3D CAD. ~~This, however, contrasts~~This contrasts with ~~another~~ study conducted in a developing country ~~that~~ showed 57% of users implemented 3D, while 8.6% don't utilize CAD at all (Sawhney et al., 2014).

Table 4 The Extent of Using CT Tools

Tools	Mean	Rank
Autodesk	2.51	1
Microsoft Office	2.38	2
Primavera	1.99	3
Microsoft Project	1.56	4

Procore	1.43	5
Sage	1.42	6
Bluebeam	1.36	7
Dropbox	1.35	8

~~(Note: 1-Low importance, 2-Moderate Importance, 3-High importance)~~

~~The r~~Researchers ~~also~~ wanted to understand what was used as a medium for use of CT tools in ~~the industry~~VCI. As per results mentioned in Table 5, most ~~of the~~ respondents agreed ~~that~~ computer remained ~~the~~ popular medium of use. As more CT tools are developing friendly mobile phone applications, many users in ~~the~~ construction industry are beginning to use the applications. (Procore, MS Office, AutoCAD reader are examples of mobile phone applications).

Table 5 Method of Use of CT Tools

System	Frequency	Percentage
Computer	186	82.3%
Phone	37	16.4%
Tablet	3	1.3%

There are many benefits discussed in ~~the adoption of~~ CT tools ~~in construction industry~~adoption. Although most benefits cannot be directly related to financial savings, ~~the~~ authors ~~have tried~~attempted to survey the number of hours spent/saved using CT tools. Stanford University Center for Integrated Facilities Engineering calculated benefits from BIM implementation in 32 construction projects ~~that~~ are up to unbudgeted change is eliminated by 40%, cost estimation accuracy is improved by 3%, time taken to generate a cost estimate is reduced by up to 80%, conflicts can be detected in time to save up to 10% of the contract value, and project time can be reduced by up to 7% (Osunsanmi et al., 2020)~~(Enegbuma and Ali, 2011, Osunsanmi et al., 2020)~~. In accordance with ~~the~~ respondents, most ~~of them spent~~spend 3-4 hours daily using CT tools. In terms of time savings, most ~~of the~~ users agree ~~that~~ it saves them 1-2 hours in a day. Table 6 compares the time spent/saved using CT tools.

Table 6 Number of Hours Spent / Number of Time Saved using CT Tools

Time Spent on CT Tools		**Time (Minutes)**	**Time Saved using CT Tools**	
Frequency	Percentage		Frequency	Percentage
6	2.7%	< 30	58	25.7%
21	9.3%	30 - 60	70	31.0%
23	10.2%	120 - 240	33	14.6%
22	9.7%	240 - 360	19	8.4%

92	40.7%	360 - 480	21	9.3%
62	27.4%	> 480	25	11.1%

Table 7 indicates what most ~~of the~~ respondents are using CT tools for in ~~the construction industry~~VCI. Most ~~of the~~ users agree ~~that currently~~ CT tools are highly being used for construction operations, ~~reading~~ interpreting drawings and for estimation purpose. ~~Therefore, i~~~~It can be noted~~The ~~that the~~ tools ~~are being used~~are used ~~not for a particular phase of the project, but rather~~ for all phases/duration of ~~the~~ project.

Table 7 Use of CT Tools

Scope of Work	Frequency	Percentage
Request for Information	35	15.5%
Estimating	80	35.4%
Drawings	91	40.3%
Communication	33	14.6%
Construction Operations	107	47.3%
Resources Management	49	21.7%
Bidding	32	14.2%
Submittals	63	27.9%
Specifications	14	6.2%

~~The m~~Major ~~purpose of this research~~research purpose was to recognize the ~~major~~ barriers influencing the CT implementation ~~of CT~~ in ~~Vietnam's construction industry~~VCI. The ~~following were the~~ most influential were: (1) Unknown impact on productivity, (2) Late implementation of software in construction projects, (3) Lack of understanding on importance and needs in construction industry (4) Lack of funds during budget planning for technological advances and implementation (5) Lack of experts required for technological change and insufficient skills in ~~the~~ industry were identified.

When ~~the~~ barriers identified in Vietnam are compared to previous study findings, it can be noted ~~that the~~ barriers are evolving, and new challenges are found in ~~the~~ CT adoption ~~of CT~~. ~~The c~~Companies have started to implement new technologies ~~found in the industry~~available. ~~The i~~Issue they're facing is on what value it is bringing to ~~the~~ projects and ~~the~~ overall company processes. ~~The r~~Return of investment and hence productivity analysis is something that cannot be measured before or during ~~the~~ implementation. Data is required for years to compare how previous processes were not as cost effective as ~~the~~ newer ones with ~~the~~ aid of technology. ~~In addition, a~~~~Another issue faced is that t~~Currently there is no software in ~~the~~ market that can cover all processes. Hence, there is an invisible wall between departments. New programs such as Procore are trying to tackle ~~that~~ barrier by merging with other software in ~~the~~ market, but it has yet to reach maturity. Once there is a continuous flow of information and the departments are linked with one central platform, it that will allow a more comprehensive understanding of productivity.

The cConstruction industry unlike manufacturing and other respective industries it has projects that lasts for years. Many of the software Software implementation benefits when it is incorporated rightimplemented in the beginning of the projectearlier stages of project. Unfortunately, most of the failures captured are in projects that that are attempting to implement halfway. First, there was no budget planned. Secondly, high costs are incurred for training, transferring all information to the new system, and ensuring the whole team is on board. Most of the Project ManagersCM are now refraining from this exercise to avoid high risks of failures in overall performance of the respective projects.

It can also be notedThe that the current industry is suffering from understanding what software to implement and its impact on the current processes. The cConstruction industry is highly occupied and does not have the time to stop and train itself on newer/better solutions. The uUniversity and college programs are also only picking up the pace now. Over the years, the programs have been limited to Microsoft Office, Microsoft Project, Primavera and few other software trainings only. The iIndustry overall is benefiting from government mandates to improve on efficiency.

Table 8 Major barriers affecting the Adoption of CT

Factors	Mean	SD	Rank
6bUnknown impact on productivity	2.75	0.463	1
3eLate implementation of software in construction projects	2.74	0.48	2
4aLack of understanding on importance and needs in construction industry	2.73	0.484	3
3dLack of funds during budget planning for technological advances and implementation	2.72	0.481	4
3fLack of experts required for technological	2.69	0.51	5

~~change and insufficient skills in the industry were identified~~			
2a~~Lack of human expertise, capability, client knowledge and training~~	2.68	0.529	6
2e~~Staffing shortage on adoption of technology requires new roles/responsibilities~~	2.68	0.548	7
3b~~Lack of knowledge and understanding of software in the market~~	2.67	0.518	8
5c~~Project complexity did not allow for new software to be implemented~~	2.63	0.554	9
5g~~High training and running costs~~	2.58	0.585	10
7a~~Software capability does not match project requirements~~	2.58	0.546	11
3a~~Lack of available information on technology reliability, implementation, and benefits~~	2.57	1.432	12
2b~~Lack of support from top management~~	2.53	0.583	13
2d~~Company culture on adoption of technologies and innovation strategies~~	2.52	0.575	14
2c~~Resistance to change in the office~~	2.5	0.56	15
5d~~Long lead time required for full-~~	2.49	0.576	16

~~scale implementation~~			
4b~~Business agility / expansion~~	2.49	0.598	17
1a~~Lack of institutional policies and guidelines~~	2.49	0.642	18
5a~~High set up cost~~	2.49	0.598	19
5f~~Tax related benefits, return on investment~~	2.48	0.606	20
5b~~Risks in implementation~~	2.48	0.634	21
3c~~Lack of awareness~~	2.46	0.582	22
5e~~Legal and contractual constraints on adopting technology~~	2.42	0.684	23
6a~~Ease of maintenance~~	2.25	0.643	24
1b~~Lack of government/client mandate~~	2.24	0.644	25

~~(Note: 1-Low importance, 2-Moderate Importance, 3-High importance)~~

5.0 ~~CONCLUSIONS~~Conclusion

~~Construction technologies (~~CT~~)~~ have emerged as powerful tools that can be used to work more efficiently in ~~Architectural, Engineering and Construction (~~AEC~~)~~ applications. Reportedly, technologies such as ~~Artificial intelligence (~~AI~~)~~ as solving complex problems can be greatly enhanced by tools. ~~The i~~Implementation of CT in AEC can reduce ~~the~~ time, manpower, and material requirements, which will result in lower construction costs. A critical review of past studies was conducted, and ~~the~~ most influential recurring factors were identified by the authors in ~~Vietnam's construction industry~~VCI. From ~~the~~ study made, ~~the~~ authors conclude ~~that the~~ influential factors in adoption of measurement, evaluation, and discussion of CT are significant aspects.

Construction continues to be impacted by changes and innovations resulting from ~~the~~ rapid advancement of technology. CT plays an important role in ~~the~~ continued digitalization of ~~the~~ industry. Based on ~~the~~ findings, ~~the~~ authors have proposed the following recommendations to foster CT adoption in construction projects in Vietnam:

~~The Government of Vietnam~~Vietnam's government ~~has to~~must allocate more budget and introduce mandates ~~that will~~to promote ~~the~~ CT adoption ~~of construction technology~~. ~~Also, the~~ Government should provide tax deductions, organize conferences, and require technology in all public projects. This will address ~~one of~~ the ~~influential factors "Lack of funds during budget planning for technological advances and implementation".~~factor 3d. ~~The~~ Government mandates will create ~~more~~ awareness for ~~the~~ CT potential and address cost savings in ~~the~~ long run. It will ~~also~~ provide more data for researchers and increase ~~the~~ sample size for review, allowing better tools to be created in ~~the~~ long run and improve ~~the~~ efficiency of the projects.

~~The c~~Colleges and universities ~~have to~~must review their curriculum to become the ~~centre~~center for learning latest technologies in place. ~~The c~~Companies should partner with ~~the~~ University Scholars to ensure ~~all~~ graduates are equipped with latest technologies in place. This will address ~~one of~~ the ~~influential factors "Lack of experts required for technological change and insufficient skills in the industry were identified"~~factor 3f. ~~The e~~Educational institutions play a significant role in being ~~the~~ first to introduce technologies that are ~~most commonly used~~most used in different types of construction projects. Having a knowhow of the tools and a good understanding of its abilities in the back of your mind will benefit when problems arise.

Project owners should encourage contractors and all respective stakeholders to find more efficient methods (~~also~~ known as value engineering). Monthly training programs should be implemented at ~~the~~ construction office to learn better methods. This in turn will address ~~"Late implementation of software in construction projects"~~factor 3e. It is easier to implement construction technologies during planning stage. The consultants play a key role in understanding and making projects more efficient by using software's. It ~~also~~ aids in saving costs. Contractors need to maintain ~~that~~ consistency in implementation by budgeting for it in advance and having training programs for ~~all~~ new staff members to continue to ~~the~~ use and connect ~~the~~ dots from start to finish.

~~In order to~~To facilitate ~~the~~ learning and adoption of CT during construction projects, professional agencies and construction enterprises should procure all ~~the~~ necessary CT software. Construction companies should use data to create strategies which will align the company's vision with ~~the implementation~~software implementation ~~of software~~. Models and framework can be created specific to ~~the~~ scope of work of ~~the~~ business.

It is expected ~~that~~ the current article can serve as a framework for similar studies in ~~the~~ construction industry in other regions, based on ~~the~~ methodology proposed in this study for ~~the~~ identification of factors in ~~the~~ CT adoption ~~of CT~~ in AEC. By doing so, it can help to improve ~~the~~ overall productivity of construction projects by facilitating efficient planning and management. More studies will ~~also~~ validate ~~the~~ accuracy of results obtained in this study.

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