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Cloud-Based Real-Time Collaboration in the Construction Planning Phase: Adoption, Implementation and Success Factors Explored

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Abstract: The construction industry is confronted with persistent challenges in the enhancement of project planning and collaboration to enhance efficiency and performance. Nevertheless, recent technological advancements have introduced cloud-based real-time collaboration (CRTC) tools as promising solutions for streamlining project planning processes. The objectives of this research are: (1) to investigate the current adoption and tools of CRTC in the construction industry within the project planning phase, (2) to identify the implementation of construction projects that adopted CRTC and (3) to analyse the critical success factors that contribute to the adoption of CRTC in the construction industry. The quantitative method was employed, utilising a structured questionnaire survey to gather data from 120 respondents who represent various construction industry players. The research findings highlighted that the current adoption is "moderately familiar" with CRTC in the construction industry and the implementation of construction projects is "significantly better" when CRTC is adopted. Five key factors impact the successful adoption of CRTC tools into construction project planning processes: (1) top management support, (2) budget and cost, (3) data security and privacy, (4) compatibility and (5) perceived industry pressure. By comprehending and identifying these factors, construction stakeholders can develop targeted strategies to effectively expedite the adoption of CRTC tools. Furthermore, this research contributes to the expanding body of knowledge on digital transformation within the construction industry and provides valuable insights for decision-makers, project teams and technology providers. The research was aligned with the Construction 4.0 Strategic Plan (2021–2025), Malaysian Digital Economic Blueprint and Sustainable Development Goals no. 9. Additionally, the outcomes of this research have the potential to cultivate a collaborative environment within the construction industry, resulting in improved project planning and execution, reduced project delays and enhanced overall project outcomes.

Keywords: Cloud-based real-time, Collaboration, Project planning, SDG no. 9, Construction 4.0

INTRODUCTION

Construction project planning is an essential element in the overall success of a construction venture, as highlighted by Mohd Fateh and Nikmat (2023). Adequate planning helps guarantee that projects are finished on schedule, within budget and to the required quality standards. It involves several stages, such as site assessment,

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design, budgeting, scheduling and resource allocation – each interdependent and essential for project success. Site assessment involves evaluating the feasibility of a project and recognising potential risks and challenges. Proper project planning can have a major effect on the Malaysian economy by increasing the efficiency and effectiveness of construction projects, which are major drivers of economic growth in Malaysia. When projects are successfully planned and executed within budget, investors gain confidence and are more inclined to invest in this lucrative industry, creating job opportunities as well as stimulating economic expansion. Moreover, proper project planning can enhance the quality and safety of construction projects, decreasing the risk of accidents, delays, or cost overruns. This results in cost savings as well as increased productivity levels that ultimately benefit Malaysia's economy. Even though it takes some time to construct a project plan, it is time well spent because it will save a lot of time once the project is underway. When there is no planning, several problems can arise, including delays in the supply of materials, machinery and project operations, which results in significant losses of time and money, as reported by Abdulkareem (2020). Construction project planning often entails complex tasks that necessitate effective communication, coordination and real-time updates among project stakeholders. Traditional methods of project planning can be inefficient and time-consuming, leading to potential errors and difficulties with change management.

According to Baduge et al. (2022), the construction industry has made minimal progress due to its slow adoption of digitalisation, which is disrupting how traditional procedures are done. Slow adoption of new technologies is another hurdle that the construction industry must be facing, which is essential for staying competitive and achieving sustainable growth. Many construction companies remain hesitant to invest in these initiatives due to concerns over cost, training requirements and adoption. CIDB (Construction Industry Development Board) launched Construction 4.0 in 2020, which is a roadmap for the Malaysian construction industry to embrace the Fourth Industrial Revolution (IR 4.0) in ways that would transform its productivity, competitiveness and new technological adoption. The aim of Construction 4.0 is to alter the construction sector in Malaysia by enabling smart construction for the next generation of society. This is in line with the government's aspiration to urge the players in the construction industry to implement new ideas and technology for the future of the industry.

As a result, many cutting-edge technologies have emerged in the construction industry, among them cloud-based real-time collaboration (CRTC). Oraee et al. (2019) have acknowledged the enormous potential of CRTC to enhance team synergy; however, challenges still exist, such as poor communication and incorrect data interpretation due to decisions made during different stages of projects, as well as instances of local optimisation in the CRTC platform. However, not much was understood regarding how the CRTC would operate and function. Al-Ashmori et al. (2020) report that most construction organisations remain unaware of the CRTC, while its potential benefits remain obscure, making adoption an uphill struggle for many players involved with construction.

This scenario motivates the need for this study, which will be carried out following the goals of Construction 4.0 and to enhance local players' competitive skills as stated by the CIDB (2020). This is in parallel with Sustainable Development Goal no. 9, which is to upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of new technology processes. Therefore, the objectives of this research are: (1) to investigate the current adoption and tools of CRTC in the construction industry within the project planning phase, (2) to identify the implementation of construction projects that adopted CRTC and (3) to analyse the critical success factors that contribute to the adoption of CRTC in the construction industry.

LITERATURE REVIEW

The Construction Industry as a Vital Sector of the Malaysian Economy

The development of the world economy is significantly influenced by the construction industry. Statistics over the past 40 years have shown a strong correlation between the global construction sector and economic growth, as highlighted by Dehdasht et al. (2021), Lopes, Oliveira and Abreu (2017) and Musarat, Alaloul and Liew (2021). The construction industry has grown to be one of the most significant sectors of the Malaysian economy. Numerous industries depend on the construction industry for growth and sustainability and the construction industry has a two-fold multiplier effect on those sectors, as stated by Rashidi and Ibrahim (2017). The Malaysian construction industry, which creates job opportunities annually, contributes significantly to socioeconomic progress by offering sources of revenue and employment.

Compared to other industries, the construction process is the most complicated, making it very challenging to deal with the growing complexity of large construction projects, as summarised by Lee et al. (2020) and Oesterreich and Teuteberg (2016). The construction industry has been identified as one of the least efficient sectors due to ineffective productivity and efficiency measures that lead to costly rescheduling and rework that ultimately cause cost overruns, as described by Alreshidi, Mourshed and Rezgui (2017). In contrast to other businesses, the construction industry adopts new technologies less frequently because its distinctiveness makes it difficult to absorb innovations that are already prevalent in many other sectors, as mentioned by Craveiro et al. (2019). The inefficiency and low productivity of organisations, the demand for skills and experience and labour-saving technology were some of the issues identified by Zuhairy, Iberahim and Ismail (2015).

The Construction Industry and Cloud-Based Real-Time Collaboration

The Malaysian construction sector still relies heavily on unskilled manual labour, which lowers productivity and has a low acceptance rate for technology. Soto et al. (2019) highlighted that construction industry players can no longer avoid implementing the necessary technologies that will ensure their competitiveness through higher efficiency and productivity due to the growing complexity of construction projects as well as the demand for time reduction, quality improvement and cost reduction. Nonetheless, the majority of operations in a construction project are done manually, which may increase the likelihood of human error, which might result in faulty judgements and delays. Worldwide, the construction sector has experienced costly cost overruns and subsequent delays, as reported by Ishak, Alauddin, and Ibrahim (2019), Smith (2014) and Tahir et al. (2018).

The construction sector has a reputation for being slow to adapt to innovations and is often considered one of the least innovative industries, leaving it vulnerable to increased competition from foreign players who have invested heavily in modern equipment. According to Khudzari, Rahman and Ayer (2021), low technology adoption, ineffective planning and project management, unskilled labour, high input costs, a lack of resources in construction, post-construction waste and an accident-prone climate are all contributing factors to the industry's low productivity. This was echoed by Zhang, Cao and Wang (2018), who stated that challenges in the construction industry include low efficiency, poor safety management and productivity deficits. All of the issues highlighted lie primarily at the interface between design and construction due to delays and cost overruns caused by errors or variations from plans during execution.

Zuhairi, Mohd Fateh and Hong (2022) highlighted that team integration issues due to ineffective collaboration and communication, as well as team conflict, may cause construction projects to experience reduced productivity and efficiency, resulting in lower profits and greater expenditure on these endeavours. Timing and accuracy of information dissemination to all relevant parties are integral elements for effective decision-making in construction projects, which can be seen as information-intensive ventures. Moreover, previous studies by Oraee et al. (2019) have indicated that most project teams lacked effective communication among key participants, which resulted in many challenges during the design and adoption stages of the project. This resonated with Diener, Oishi and Tay (2018), who highlighted that effective communication among members was found to assist the entire team in establishing a conducive working environment by nurturing positive interactions and subsequently enhancing the synergy between team members. Jiancheng et al. (2021) also emphasise the significance of this aspect when compared to other industries like manufacturing.

The construction sector's productivity is very low due to several issues that have restricted its growth. Bughin et al. (2017) added that construction industry professionals have always resisted change, making it one of the least digitalised sectors. Cost overruns, project delays, poor quality outputs, ineffective decision-making skills and slow productivity results have all been linked with a lack of digital skills and technology adoption by businesses in the construction industry. Just recently, the construction industry has begun investing more heavily in researching digital technology as businesses recognise its benefits for operations and productivity, as reported by Grover, Kar and Dwivedi (2022). Given the COVID-19 pandemic and all the issues highlighted, it has become evident that construction must employ cutting-edge technologies, such as cloud real-time collaboration. Cloud real-time collaboration in construction project planning remains underutilised and needs further study to assess its role in mitigating traditional approaches' shortcomings.

The issues highlighted the pressing need for thorough research to effectively address the existing gap by analysing the critical success factors that have the potential to expedite the seamless adoption of CRTC in the Malaysian construction industry. This study strives to provide invaluable insights by meticulously examining the prospects of CRTC within the construction industry, thereby illuminating the key factors that contribute to the adoption of CRTC in the construction industry. Ultimately, the research findings will foster a profound and enriched understanding of the pivotal role CRTC plays in revolutionising the construction industry.

Cloud-Based Real-Time Collaboration Technology

The concept can be traced back to the collaboration theory. Wood and Gray (1991) describe collaboration as a "process of joint decision-making among key stakeholders about the future of a domain". In the context of the construction industry, it is a process of collaborative decision-making among stakeholders in a construction project by sharing information in real time to meet the challenges that the client and the team face. There are three types of cloud-based technology collaborative solutions, as highlighted by Heap, Balamuralithara and Chong (2011) and Yap, Abdul-Rahman and Chen (2017), as follows:

1. Software as a Service (SaaS): A service that allows users to use a software application over the internet by connecting to the service provider through a browser. Examples of SaaS include Salesforce.com, Rackspace Google Docs, Google app, Yahoo Mail and Microsoft Office Live (Zhang et al., 2022; Wong et al., 2014). SaaS is suitable for small businesses as the service provider maintains and manages the software and hardware
2. Platform as a Service (PaaS): Users can develop their applications and transfer them to other clients via the Internet. The advantage of PaaS is that it allows end-users to develop their applications, libraries and tools to support their services using programming languages. Zhang et al. (2022) and Tao et al. (2011) listed a few PaaS examples, such as Google App Engine, Force.com, 800App and Mircosoft Azure.
3. Infrastructure as a Service (IaaS): The service provider provides only the hardware, such as storage, virtualisation and processing capacity. End-users only pay for the hardware and can deploy the software to provide services for their clients. IaaS can dramatically decrease the hardware cost for end-users (Mell and Grance, 2011). Examples of IaaS include Amazon's EC2, GoGrid's Cloud Servers, Joyent and Flexiscale.

CRTC technology has experienced rapid growth over recent years due to the increase in popularity of remote work and virtual teams. This technology enables individuals and teams to work on projects together, regardless of their physical location. According to Wood (2020), the global cloud-based collaboration market is projected to increase from USD23.39 billion in 2020 to USD43.11 billion by 2025 at an expected compound annual growth rate of 12.9% over that forecast period; increasing demand for remote collaboration coupled with efficient communication tools is driving this expansion. Cloud computing, virtualisation and edge intelligence technology are all examples of CRTC technology, as reviewed by García-Valls, Cucinotta and Lu (2014) and Ma et al. (2020).

CRTC was able to increase productivity, enhance communication and promote project management. Team members can work on projects simultaneously in real-time through this technology to collaborate and share ideas more easily; furthermore, easy access to project files and documents makes managing projects simpler than ever and allows them to track their progress more efficiently, as highlighted by Sharma and Saini (2019). The potential for cloud-based collaboration in building project management is enormous, as added by

Zhang, Cao and Wang (2018). It can deliver real-time information from the location to the headquarters while removing information delays. The reliability of on-time project delivery and staying within budget have the potential to be improved by cloud-based collaborative technologies. Therefore, collaboration was found to be essential for the success of both project execution and delivery, as pointed out by Oraee et al. (2019). Understanding the importance of collaboration is imperative for every project manager since it eliminates ambiguities, uncertainties and risks commonly identified within construction projects, as endorsed by Walker, Davis and Stevenson (2017).

Abedi et al. (2014) also revealed that construction management must include cloud-based real-time project planning. Chang, Cui and Zhong (2012) added that real-time monitoring and modelling are used to anticipate and analyse the building timeline. Planning and scheduling issues are addressed using building information modelling (BIM)-based time management, which is becoming an increasingly important component of construction projects. Project managers utilise several tools and approaches to create, monitor and control project schedules since they are a crucial component of planning construction projects, as described by Opeyemi et al. (2019). According to Dastider and Rosa (2021), the usage of CRTC technology boosts output, encourages teamwork and cuts costs. As a result, real-time monitoring and simulation, cloud computing, BIM-based time management and project scheduling tools are some of the essential tools and techniques used in construction project planning. It is hoped that the rapid advancement of technology, cloud computing and ICT, in particular, will provide opportunities to enhance collaboration in a borderless and time-zone-free setting.

Factors for cloud-based real-time collaboration adoption

Top management support

Studies on the effective adoption of information technology (IT) projects in construction companies have highlighted top management support as essential. Oraee et al.'s (2019) study found that top management support had an enormous influence on the adoption of BIM by Chinese construction companies. The researcher stated that top management support could assist employees in adapting to cloud computing by helping overcome any resistance from employees and making necessary organisational adjustments for its use. According to Sukiman (2020), top management's large and beneficial effect on allocating financial and IT personnel resources drove their desire to embrace the technology; specifically, they should assess employee requirements as well as education and training needs as they create strategies and manage expectations around it. Top management support may take various forms, from financial assistance and involvement in the adoption process to employee education of the system's benefits and communication of the benefits of the system's features. Without this backing, staff members might resist change or implement it.

Budget and cost

Financial planning should always be an important aspect of cloud-based collaboration adoption. Ejidike and Mewomo (2023) stated that budget and cost considerations are crucial factors in the successful adoption of technology in the construction industry. Organisations need to consider all costs associated with their chosen platform – subscription fees, adoption expenses, training costs and ongoing maintenance support costs before making their investment decision and ensuring it fits within their budgetary restrictions. A cost-benefit analysis will assist in this decision process and allow them to make an informed decision that works in their favour, as highlighted by Onungwa, Olugu-Uduma and Shelden (2021). Therefore, while implementing CRTC in the construction business, budget and cost should be carefully studied to ensure success.

Data security and privacy

As construction projects involve sensitive data like designs, financial records and personal details that must remain private and secure, prioritising data security and privacy is of utmost importance when using cloud-based collaboration platforms. Correia and Martens (2023) emphasised that selecting a cloud service provider that implements effective measures for data security, access controls and backup storage is paramount to meeting any applicable data protection laws, like the General Data Protection Regulation. Security and privacy can help to avoid data breaches, cyberattacks, legal disputes and potential harm to project performance and reputation while at the same time meeting compliance with laws, regulations, standards and contracts related to data protection.

Compatibility

Ensuring compatibility between cloud-based collaboration platforms and existing construction software or systems is of utmost importance. Onungwa, Olugu-Uduma and Shelden (2021) recommended that to improve workflows and data interchange, cloud-based collaboration solutions must be compatible with current construction software or systems. Integration with project management tools, BIM software, document management systems and other relevant applications will streamline workflows and data exchange while increasing efficiency and preventing disruption during adoption.

Perceived industry pressure

Industry trends and market expectations may play a part in an organisation's decision to adopt cloud-based collaboration technologies, leading to feelings of pressure to keep up with competitors, improve project outcomes, or meet client demands. Staying abreast of industry developments while understanding their benefits will allow organisations to make well-informed decisions regarding cloud collaboration adoption. It is well supported by the study of Oke et al. (2021), which stated that an organisation's decision to embrace cloud-based collaboration technology may be influenced by perceived pressure and trends in the sector. According to Abbasi et al. (2022), competitive pressure plays a significant role in the process of adopting the technology. It is defined as the pressure exerted by external competitors in the same industry.

RESEARCH METHODOLOGY

Questionnaire Design

A questionnaire survey was used for the data collection in the study. All variables were derived from the literature review focusing on CRTC in the construction sector during the project planning phase. The questionnaire survey is divided into the following four sections:

1. Section 1: This section aims to gather information about the demographics of the respondents to identify their backgrounds and experiences. This includes their involvement in the construction sector, their participation in projects implementing CRTC technology and any challenges they may have encountered. Nominal scales have been employed in designing the questions to enable the calculation of percentages and frequencies.
2. Section 2: An extensive review of the literature, including articles, journals, conference papers, media reports and other sources, has resulted in the compilation of a comprehensive list that highlights the common problems and benefits encountered by construction industry professionals when utilising various practices and tools during the project planning phase. The main objective of this section is to examine the prevalent practices employed in the construction industry during the project planning phase and to explore the experiences of construction industry stakeholders about these practices.
3. Section 3: This section aims to delve into the adoption and utilisation of CRTC technology among construction industry players. This section offers valuable insights into the extent to which CRTC has been embraced by construction players, shedding light on its current adoption trends and patterns. Additionally, this section provides an exploration of the familiar software tools used in CRTC adoption within the construction industry.
4. Section 4: This section builds upon the comprehensive analysis of the literature to identify the key factors that contribute to the successful adoption of CRTC technology in the construction industry. This section seeks to obtain the perspective of construction industry professionals regarding these factors. Additionally, this section aims to gather recommendations and suggestions from construction players on how to effectively leverage the use of CRTC in the construction industry.

Sections 2 through 4 utilise the five-point Likert scale to gather responses from respondents that allow individuals to express their level of agreement or disagreement with any given statement or question (Omar and Mohd Fateh, 2023).

Sampling Method

This research employed snowball sampling as a means of gathering insights from respondents within the construction industry. Rather than randomly selecting individuals from an entire population, snowball sampling involves selecting initial participants who meet certain criteria before asking them to refer other potential participants; this helps ensure representation across roles while decreasing bias during data collection. The respondents for this study included clients, project managers, consultants and contractors from the construction industry. Participants must have at least an undergraduate diploma and CRTC-relevant work experience. Developers, consultants, main contractors, subcontractors and project managers from the engineering, procurement and construction management (EPCM) organisation were all included as respondents. The questionnaire was distributed using Google Forms and WhatsApp. In order to reach the respondents effectively, the questionnaire was shared via links and then dispersed amongst their project groups via platforms like WhatsApp; each project group typically contains around 10 individuals, thus increasing its reach to approximately 300 individuals. The justification for using the two platforms was that they were free-access, stable and had a familiar interface for all.

Data Analysis Techniques

The Statistical Package for the Social Sciences (SPSS) was used to analyse the data collected. Various statistical analyses were used to analyse the collected data, namely frequency, percentage and relative importance index (RII) analysis. The frequency and percentage of distributions produced using SPSS will provide a clear picture of the preferences and response patterns of the participants. The RII analysis will offer insightful information regarding the relative weighting (ranking) of various aspects, enabling a deeper comprehension of the research challenge.

FINDINGS AND DISCUSSION

Response Rate

The response rate for the questionnaire was found to be approximately 40%; that means out of an estimated 300 individuals who had the chance to take part, feedback was received from approximately 120 respondents. Even though a response rate of 40% can be considered satisfactory in many research studies, it is crucial to identify all the factors that impacted participant engagement and the response rate as a whole. This is acceptable because the typical response rate for a self-administered survey for construction research is between 20% and 30% (Mohd Fateh and Zamri, 2022).

Cronbach's Alpha

Cronbach's alpha was employed as a statistical measure of internal consistency and reliability (McNeish, 2018). Values greater than 0.7 are generally accepted as indicators of satisfactory internal consistency. In this study, a high Cronbach's alpha value of 0.877 suggests strong internal consistency across questionnaire items and effective measurement of the target construct. This result gives users confidence about the reliability of the survey and the data derived from it; some studies even recommend exceeding 0.80 or even 0.90 as desirable, according to Shila, Jayanti and Bibhav (2023) and Srivastava et al. (2022).

Respondents Demographics Profile

Table 1 shows the distribution of the 120 respondents by the sectors of their organisations. Contractors/subcontractors account for 24.2% of the respondents' total responses, closely followed by consultants (20.0%) and EPCM firms (15.8%). Each of the developer and government sectors accounts for 15.0% of responses, while the project management consultant (PMC) accounts for 8.3%. Surprisingly, with just one response apiece, the "others" and owner/client sectors have very little representation and account for 0.8% of the total. The table sheds important light on the participants' varied origins while emphasising the significant participation of contractors and consultants in the sample population. The diverse mix of industries provides valuable insight into the diverse perspectives and roles played by organisations within the construction industry. Consultants bring expertise and advisory services, contractors and subcontractors assist with project execution, developers initiate and finance projects, and EPCM companies offer comprehensive project management services, with government entities adding yet another perspective to this study.

Table 1. Organisation sector of respondents (*N* = 120)

Sector	**Frequency**	**%**
Contractor/Subcontractor	29	24.2
Consultant	24	20.0
EPCM company	19	15.8
Developer	18	15.0
Government	18	15.0
PMC	10	8.3
Others	1	0.8
Owner/Client	1	0.8
Total	120	100.0

Table 2 provides data on the years of experience of 120 respondents working in the construction industry. Respondents were divided into four groups by years of involvement: (1) Less than 3 years, (2) 3 years to 5 years, (3) 5 years to 10 years and (4) More than 10 years. The highest representation comes from respondents with 5 years to 10 years of experience, accounting for 45.8% of the overall percentage. This indicates there is an important population within the construction industry that has likely amassed significant knowledge and expertise over time. Among all, 30.0% of respondents fall within this group with 3 years to 5 years of experience, representing an ample pool of individuals relatively new to the industry but who have spent some time honing practical skills, while 13.3% of respondents had less than 3 years of experience, reflecting an emerging workforce within construction, likely including recent graduates or those newly transitioning into the field. Making up 10.8% of the total respondents, 13 respondents had at least 10 years of experience. This category likely comprises experienced professionals involved with construction for an extended period, perhaps acting in key leadership positions within their organisations. The data illustrates that the construction industry comprises professionals with various experience levels, spanning both newcomers and veterans.

Table 2. Respondent's years of involvement in the construction industry (*N* = 120)

Years of Involvement	Frequency	%
Less than 3 years	16	13.3
3 years to 5 years	36	30.0
5 years to 10 years	55	45.8
More than 10 years	13	10.8
Total	120	100.0

Level of Understanding of the Cloud-Based Real-Time Collaboration Technology

Table 3 presents the results of a survey designed to assess understanding of CRTC among 120 respondents. Most respondents (89.2%) accurately identified CRTC as a cloud-based platform that facilitates real-time collaboration among project stakeholders in construction projects using tools such as Microsoft Project Online, Oracle Aconex, Trello, Asana Synchro and Google Drive for Autodesk 360. While 4.2% of respondents reported never hearing of the term CRTC before taking part in this questionnaire survey, only 3.3% of respondents mistook the CRTC as being related to virtual reality technology or as an approach that emphasises clear communication and efficient coordination in construction projects. This suggests that a sizeable fraction of respondents have an in-depth understanding of CRTC technology, pointing to a group of experts or people knowledgeable about the nuances and real-world applications of this technology, thus making their inputs reliable for the research.

Table 3. Level of understanding of CRTC technology (*N* = 120)

Level of Understanding	Frequency	%
CRTC refers to a cloud-based platform that allows real-time collaboration between project stakeholders in construction projects, such as the use of Microsoft Project Online, Oracle Aconex, Trello, Asana, Synchro, Google Drive, Microsoft OneDrive and Autodesk 360	107	89.2
I have never heard of the term CRTC before	5	4.2
CRTC is a term used to describe the use of virtual reality technology in the construction industry	4	3.3
CRTC is a method of project management that emphasises the use of clear communication and efficient coordination	4	3.3
Total	120	100.0

Current Adoption and Tools of Cloud-Based Real-Time Collaboration in the Construction Industry Within the Project Planning Phase

Table 4 summarises the adoption of CRTC technology among construction players during the project planning stages, according to responses from 120 participants. It categorises respondents according to their familiarity levels with CRTC technologies. "Moderately Familiar" represents the highest level of familiarity, with 45.0% of respondents falling under this category. Next comes "Very Familiar," with 31.7% demonstrating high levels of comfort with the technology behind CRTC systems. Finally, 13.3% indicated an extensive understanding of CRTC technology solutions. On the other hand, only a smaller proportion of respondents fall into less familiar categories: 6.7% fall under "Somewhat Familiar," with 3.3% placing themselves under "Not at All Familiar." The findings display various levels of knowledge and adoption of CRTC technology among construction players during the project planning stages. The findings can provide stakeholders and decision-makers in the construction industry with valuable insight into current levels of adoption as well as opportunities for further education or adoption efforts.

Table 4. Adoption of CRTC technology among construction players during project planning phase (*N* = 120)

Adoption Rate	Frequency	%
Moderately familiar	54	45.0
Very familiar	38	31.7
Extremely familiar	16	13.3
Somewhat familiar	8	6.7
Not at all familiar	4	3.3
Total	120	100.0

Table 5 provides insights into the use of CRTC technologies or tools across different organisations. Autodesk BIM360 and Procore were the two most frequently chosen tools, representing approximately 30.11% and 28.96% of respondents, respectively. The popularity of these tools attests to their effectiveness in streamlining construction projects and facilitating real-time collaboration among all parties involved. PlanGrid, Asite and Autodesk Construction Cloud were also popular with participants; each was chosen at random by 17 respondents out of 25 total respondents, representing 9.29%, 2.19% and 2.73% of total responses, respectively. Aconex earned 14 selections out of 75 respondents, accounting for 7.65%. This affirmation confirmed its importance within the industry as well. However, 21 participants (11.48%) reported not using any CRTC technologies or tools surveyed, suggesting there may be gaps in technology adoption that organisations need to address to increase efficiency, collaboration and project management. This evidence emphasises the significance of technological advancements within construction as well as calling for further research and awareness campaigns encouraging greater adoption and utilisation of CRTC tools that drive forward the industry.

Table 5. CRTC tools used by respondent in their organisations (N = 120)

CRTC Tools	Frequency	%
Autodesk BIM360	55	30.11
Procore	53	28.96
None	21	11.48
PlanGrid	17	9.29
Aconex	14	7.65
Autodesk Construction Cloud	5	2.73
Asite	4	2.19
Synchro	3	1.64
Bluebeam Revu	3	1.64
Trimble Connect	1	0.55
Total	120	100.00

The Construction Projects that Have Adopted Cloud-Based Real-Time Collaboration Technology Compared to Traditional Methods

Table 6 compares the construction projects using CRTC technology with those using traditional methods. Findings show that an overwhelming majority of respondents, 67.5%, reported that construction projects employing CRTC technology performed significantly better than traditional methods; this indicates a positive influence of CRTC technology on project outcomes as perceived by participants. Another 29.2% of respondents indicated that construction projects using CRTC technology had "Moderately Better" results when compared with traditional methods, suggesting CRTC adoption still yielded positive outcomes for many projects despite not producing as significant an effect as its use had in "Significantly Better" categories. 2.5% of respondents reported that projects using CRTC technology showed only "Slightly Better" performance, which may still indicate some projects experienced slight performance gains by adopting this technology. Although this number may seem low, it shows how some projects experienced subtle gains because of CRTC adoption. Oddly, 0.8% of respondents indicated "No Difference" in performance between projects using CRTC technology and traditional methods, which suggests that its adoption did not result in noticeable performance differences for any number of projects. Notably, no respondents reported projects using CRTC technology performing "Slightly Worse", "Moderately Worse" or "Significantly Worse" than those employing traditional methods, suggesting CRTC is not associated with decreased project performance in participants' perceptions.

The findings show that the adoption of CRTC technology in construction projects is generally seen as highly advantageous, with most respondents reporting better performance compared to traditional methods. This evidences the powerful impact of CRTC in improving project outcomes and overall efficiency, yet further investigation may be required into specific factors contributing to performance enhancement as well as ways in which adopting CRTC can yield even greater returns. Okereke, Ihekweme and Adegboyega (2022) provide further evidence to back this claim when they study the impact of traditional procurement systems on construction project delivery. Their study highlighted the adverse consequences associated with sequential and linear natures on time, cost and quality performance for projects. In contrast to these methods, CRTC technology may enhance project performance by streamlining communication and collaboration management more than its traditional equivalent.

Table 6. The construction projects that have adopted CRTC technology compared to those relying on traditional methods (*N* = 120)

Implementation	**Frequency**	**%**
Significantly better	81	67.5
Moderately better	35	29.2
Slightly better	3	2.5
No difference	1	0.8
Slightly worse	–	–
Moderately worse	–	–
Significantly worse	–	–
Total	120	100.0

Responses show that CRTC tools offer significant advantages over conventional approaches in construction project planning and coordination. Positive perspectives shared by respondents suggest that CRTC technologies can revolutionise and optimise construction project management practices. Table 7 provides insight into how CRTC tools compare with traditional methods of project planning and coordination, with several recurring themes:

1. Improved collaboration and communication: Many respondents reported that CRTC tools improve collaboration and communication among team members, facilitating seamless updates and data sharing in real-time, making it easier for teams to work effectively together.

2. Organisation and data management: According to several respondents, CRTC tools were more organised, structured and managed than traditional methods, suggesting they offer systems that facilitate efficient project planning and data organisation.
3. Real-time saving and data security: Respondents also emphasised the real-time saving capabilities and data protection provided by CRTC tools, emphasising their significance in protecting project information. This highlighted just how CRTC tools contribute to protecting vital project details.
4. Efficiency and automation: Input from respondents showed that CRTC tools are fast, effective and more automated than conventional methods, leading to reduced manual effort while speeding up processing tasks, resulting in enhanced project planning and coordination efficiencies.
5. Reducing physical storage and paper consumption: Some respondents reported that CRTC tools can significantly decrease physical storage requirements as well as paper document consumption, reflecting the potential environmental advantages of digital tools for project management, leading to an eco-friendly solution.

Table 7. How do these CRTC tools compare to more conventional methods of project planning and coordination?

Respondent	Respondent's Perspective
1	Easier utilisation for interfacing of various team members and more seamless real-life updates
2	Well-managed and organised
3	Good in real-time saving and data protection
4	Enables better collaboration with less effort required to do it
5	Not sure
6	More organised and easy-to-track documents and drawings
7	Proper communication between construction players, proper planning and record keeping and easier data sharing everywhere, anytime
8	They provide transparency and are more structured
9	Fast and effective
10	Better info is distributed for all sectors
11	CRTC allow for easier access to protect data and information from anywhere
12	Provide a higher level of security and data protection compared to conventional methods
13	Easy sharing and collaboration of documents and files, reducing the need for time-consuming and error-prone email chains and manual file transfer
14	Able to reduce the need for physical storage and paper documents
15	CRTC is more automated compared to traditional

Critical Success Factors that Contribute Adoption of Cloud-Based Real-Time Collaboration Technology towards Enhancing Project Planning Efficiency in the Construction Sector

Based on the results presented in Table 8, this study identifies five critical success factors that contribute to the adoption of CRTC technology in the construction industry. The analysis utilised the RII and ranking method. These factors encompass top management support, budget and cost, data security and privacy, compatibility and perceived industry pressure. The critical success factors were ranked on a scale of 1 to 5, offering an overall assessment of each factor's importance in the successful adoption of CRTC technology in the construction industry.

Table 8. Critical success factors that contribute to the adoption of CRTC (*N* = 120)

Factors	Percentage of Respondents Scoring					RII	Ranking
	1	2	3	4	5		
Top management support: Top management is key to driving change by adopting innovations and technology	–	0.80	0.80	50.9	51.8	0.777	1
Budget and cost: Budget allocation should occur if the new method of adoption proves to be trustworthy	–	–	4.20	49.2	50.9	0.773	2
Data security and privacy: The negligence of employees is one of the biggest security dangers	–	–	–	43.4	50.8	0.791	3
Compatibility: The CRTC software should be user-friendly and easy to use for the organisation's employees	–	–	–	45.0	55.0	0.758	4
Perceived industry pressure: The benefits are significant when you have a successful application of technology	–	–	–	45.8	54.2	0.757	5

Top management support

The first factor is top management support. This signifies the critical role of top management in supporting and championing the adoption of CRTC technology in the construction industry. The strong endorsement and commitment from top management are essential for driving successful adoption, overcoming potential challenges and ensuring the necessary resources and support are provided for a smooth adoption process. It received the highest RII score of 0.777 and was ranked first out of the 20 factors. This suggests that top management's active involvement and leadership are critical to successfully implementing the CRTC.

Table 8 emphasises the key role played by top management support, leadership and investments in resources as key drivers in successfully implementing the CRTC. Their commitment and active involvement are necessary to overcome any potential hurdles or difficulties and facilitate their organisation's smooth transition towards adopting cutting-edge innovations like the CRTC. This statement is supported by Oraee et al. (2019), who emphasised in their study the critical role of top management support in overcoming barriers and promoting effective collaboration through cloud-based collaboration and data management platforms. This finding is further supported by Alreshidi, Mourshed and Rezgui (2018), who highlighted the importance of top management expressing support and commitment to goals to initiate collaboration in construction projects. Additionally, previous research by Onungwa, Olugu-Uduma and Shelden (2021) emphasised that top management support is necessary for the successful adoption of cloud BIM. This support facilitates seamless communication, real-time progress monitoring and file visualisation.

Budget and cost

The second factor is the budget and cost associated with the adoption of CRTC technology in organisations. It is crucial to evaluate the financial resources available and allocate costs effectively when investing in CRTC technology. Based on the findings, this factor ranks second, indicating its significant importance in the adoption process. The organisation needs to allocate a sufficient budget to acquire and maintain the necessary hardware, software and infrastructure required for implementing such solutions, receiving the highest RII score of 0.773. Organisations tend to allocate budget resources towards CRTC adoption when they trust its reliability and potential benefits.

Budget and cost considerations play a critical role in the successful adoption of CRTC technology. Organisations should allocate adequate resources, plan an annual innovation budget provision and evaluate the trustworthiness of technology to ensure a seamless adoption process that can unlock all its potential, leading to enhanced collaboration and productivity benefits. Nagendra and Rafi (2018) reinforce this assertion, arguing that budget slack allows enterprises to investigate new concepts and allocate financial resources for investment in innovation. Ejidike and Mewomo (2023) also emphasised the need for budget and cost concerns for the successful use of technology in the construction sector.

Data security and privacy

The third factor is the data security and privacy concerns associated with utilising CRTC tools. This signifies the substantial significance placed on safeguarding data and ensuring privacy in the adoption of CRTC technology. It highlights the need for organisations to address these concerns effectively to gain trust and facilitate widespread adoption within the industry. The findings highlighted that employee negligence as a security danger earned an RII score of 0.761 and was placed third amongst all factors evaluated, emphasising the need for training and awareness programmes designed to mitigate potential security threats caused by employee actions or oversight.

Organisations that prioritise data security establish a solid foundation for their business operations and relationships. The significance of data security and privacy considerations becomes apparent when deploying CRTC tools, highlighting their relevance in today's context. By proactively addressing these concerns, organisations can mitigate security vulnerabilities while benefiting from the advantages offered by CRTC solutions. This viewpoint is supported by Shamim (2022), who emphasised the importance of investing in robust security measures to minimise the costs associated with security breaches.

Compatibility

The compatibility of implementing CRTC technology in organisations ranked as the fourth factor that contributes to the adoption of CRTC. Ensuring compatibility involves assessing whether existing infrastructure, software and systems can accommodate this new technology. By addressing compatibility issues, organisations can minimise disruptions while optimising integration into operations, ultimately leading to improved collaboration and communication within construction industry operations. The findings suggested that having a user-friendly and easy-to-use interface for the CRTC software is crucial for successful adoption; it received the highest RII score (0.758), which indicates that the user experience and ease of use play a significant role in driving adoption and effectiveness.

Compatibility is essential to the successful adoption of CRTC technology, facilitating seamless integration, encouraging data sharing and decreasing resistance to change while increasing overall efficiency and productivity. A system that is user-friendly and adaptable enough to integrate into an organisation's existing tech infrastructure will lead to increased user acceptance and better outcomes. This statement is supported by Phillips-Wren and McKniff (2020), who highlighted that by providing a clear and user-friendly interface, interactive data visualisation can enhance compatibility and increase acceptance of new technologies.

Perceived industry pressure

The last factor is perceived industry pressure, which holds a significant position as the fifth. The significance of successful application and the perceived significance of benefits arising from the successful adoption of CRTC technology play a vital role in adoption decisions. This factor achieved a high RII score (0.757), suggesting organisations are more likely to adopt it when they see tangible and substantial returns from the successful adoption of it. Perceived industry pressure plays an instrumental role in shaping organisations' adoption of CRTC technology. Organisations tend to adopt innovative systems like the CRTC when they see tangible benefits, recognise successful applications within their field and realise competitive advantages through such adoptions. Market demand and customer expectations also drive organisations towards exploring and adopting this type of innovation in response. How the industry pressure and competitive advantage might shape and influence the direction regarding technology adoption, as stressed by Abbasi et al. (2022). According to Subramanian, Patil and Gardas (2021), intense competition is a key element in manufacturing micro, small and medium firms' decisions to use cloud computing. Furthermore, Fu et al. (2023)

emphasised the importance of industry characteristics and competitive pressure in encouraging enterprises to adopt cutting-edge technologies. Collectively, these data provide strong evidence in favour of the idea that perceived industry pressure and competitive advantage play a significant role in influencing decisions about the adoption of new technologies.

CONCLUSIONS

In conclusion, this study is significant as it can advance the goals of IR 4.0 and Construction 4.0 in the landscape of the construction industry in Malaysia. to increase productivity, efficiency and sustainability while at the same time making projects faster, more efficiently completed and more affordably and rapidly completed. The research findings highlighted that CRTC can be a potential tool to enhance communication and coordination during project planning. The technology could be expanded to offer stakeholders real-time data management of the project's present status and to simplify the evaluation of other solutions. CRTC will also benefit project outcomes while decreasing costs, which could have far-reaching ramifications for the construction industry. Furthermore, it may lead to new methods and tools being created specifically for use with CRTC-enabled project planning. This research could also serve to bridge the gap between the academic and construction industries. The findings could significantly contribute towards digitalising and automating construction sites for more efficient and sustainable built environments, in line with the 12 developing technologies outlined in the Construction 4.0 Strategic Plan (2021–2025) acting as the primary accelerator.

Building on the research findings, future research will be conducted to monitor the long-term consequences of the use of CRTC technology in construction project planning. It is possible to conduct comparative studies to evaluate the performance of various CRTC technologies in various building industries. Insightful information may also be gained by examining the direct effects of CRTC technology adoption on project performance measures like schedule adherence and cost management. Collaboration may be improved even further by integrating CRTC tools with BIM systems and taking security and data privacy considerations seriously. It will also be helpful to investigate regional views and the effects of organisational culture and change management on the adoption of CRTC technology.

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REFERENCES

Abbasi, G.A., Rahim, N.F.A., Wu, H., Iranmanesh, M. and Keong, B.N.C. (2022). Determinants of SME's social media marketing adoption: Competitive industry as a moderator. *SAGE Open*, 12(1). https://doi.org/10.1177/21582440211067220

Abdulkareem, S. (2020). Methods of project planning for construction projects. Available at: https://www.researchgate.net/publication/338541301

Abedi, M., Rawai, N.M., Fathi, M.S. and Mirasa, A.K. (2014). Cloud computing as a construction collaboration tool for precast supply chain management. *Jurnal Teknologi (Sciences and Engineering)*, 70(7). https://doi.org/10.11113/jt.v70.3569

Al-Ashmori, Y.Y., Othman, I., Rahmawati, Y., Amran, Y.H.M., Sabah, S.H.A., Rafindadi, A.D. and Mikić, M. (2020). BIM benefits and its influence on the BIM implementation in Malaysia. *Ain Shams Engineering Journal*, 11(4): 1013–1019. https://doi.org/10.1016/j.asej.2020.02.002

Alreshidi, E., Mourshed, M. and Rezgui, Y. (2018). Requirements for cloud-based BIM governance solutions to facilitate team collaboration in construction projects. *Requirements Engineering*, 23(1): 1–31. https://doi.org/10.1007/s00766-016-0254-6

______. (2017). Factors for effective BIM governance. *Journal of Building Engineering*, 10: 89–101. https://doi.org/10.1016/j.jobe.2017.02.006

Baduge, S.K., Thilakarathna, S., Perera, J.S., Arashpour, M., Sharafi, P., Teodosio, B., Shringi, A. and Mendis, P. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction*, 141: 104440. https://doi.org/10.1016/j.autcon.2022.104440

Bughin, J., Hazan, E., Ramaswamy, S., Chui, M., Allas, T., Dahlström, P., Henke, N. and Trench, M. (2017). Artificial intelligence the next digital frontier? Available at: http://www.mckinsey.com/mgi

Chang, J., Cui, B. and Zhong, D.H. (2012). Research on construction schedule real-time control of high core rock-fill dam based on digital monitoring. *Advanced Materials Research*, 588–589: 1062–1067. https://doi.org/10.4028/www.scientific.net/AMR.588-589.1062

CIDB (Construction Industry Development Board) (2020). *Construction 4.0 Strategic Plan (2021–2025) Next Revolution of the Malaysian Construction Industry*. Kuala Lumpur: CIDB.

Correia, S.R.V. and Martens, C.D.P. (2023). Cloud computing projects: Critical success factors. *RAUSP Management Journal*, 58(1): 5–21. https://doi.org/10.1108/RAUSP-06-2021-0107

Craveiro, F., Duarte, J.P., Bartolo, H. and Bartolo, P.J. (2019). Additive manufacturing as an enabling technology for digital construction: A perspective on Construction 4.0. *Automation in Construction*, 103: 251–267. https://doi.org/10.1016/j.autcon.2019.03.011

Dastider, S.G. and Rosa, L. (2021). A cast study to investigate an affordable cloud-based server for worksharing to benefit academia and small businesses. *International Journal of Scientific Research and Management*, 9(4): 39–46. https://doi.org/10.18535/ijsrm/v9i04.cs01

Dehdasht, G., Ferwati, M.S., Abidin, N.Z. and Oyedeji, M.O. (2021). Trends of construction industry in Malaysia and its emerging challenges. *Journal of Financial Management of Property and Construction*, 27(2): 161–178. https://doi.org/10.1108/JFMPC-08-2020-0054

Diener, E., Oishi, S. and Tay, L. (2018). Advances in subjective well-being research. *Nature Human Behaviour*, 2(4): 253–260. https://doi.org/10.1038/s41562-018-0307-6

Ejidike, C.C. and Mewomo, M.C. (2023). Benefits of adopting smart building technologies in building construction of developing countries: Review of literature. *SN Applied Sciences*, 5(2): 52. https://doi.org/10.1007/s42452-022-05262-y

Fu, H.P., Chang, T.H., Lin, S.W., Teng, Y.H. and Huang, Y.Z. (2023). Evaluation and adoption of artificial intelligence in the retail industry. *International Journal of Retail and Distribution Management*, 51(6): 773–790. https://doi.org/10.1108/IJRDM-12-2021-0610

García-Valls, M., Cucinotta, T. and Lu, C. (2014). Challenges in real-time virtualisation and predictable cloud computing. *Journal of Systems Architecture*, 60(9): 726–740. https://doi.org/10.1016/j.sysarc.2014.07.004

Grover, P., Kar, A.K. and Dwivedi, Y.K. (2022). Understanding artificial intelligence adoption in operations management: Insights from the review of academic literature and social media discussions. *Annals of Operations Research*, 308(1–2): 177–213. https://doi.org/10.1007/s10479-020-03683-9

Heap, Y.C., Balamuralithara, B. and Chong, S.C. (2011). Construction contract administration in Malaysia using DFD: A conceptual model. *Industrial Management and Data Systems*, 111(9): 1449–1464. https://doi.org/10.1108/02635571111182782

Ishak, M.F., Alauddin, K. and Ibrahim, M.S.H. (2019). Late and non-payments issues in the Malaysian construction industry: Perspective of building material suppliers. *Malaysian Journal of Sustainable Environment*, 6(1): 39–56.

Jiancheng, S., Changsaar, C., Hunchuen, G. and Yaoli, X. (2021). Enhancing project integration using cloud-based building information modelling: A conceptual model. *International Journal of Advanced Research in Technology and Innovation*, 3(3): 12–25.

Khudzari, F., Rahman, R.A. and Ayer, S.K. (2021). Factors affecting the adoption of emerging technologies in the Malaysian construction industry. *IOP Conference Series: Earth and Environmental Science*, 641(1): 012006. https://doi.org/10.1088/1755-1315/641/1/012006

Lee, Y.C., Shariatfar, M., Rashidi, A. and Lee, H.W. (2020). Evidence-driven sound detection for prenotification and identification of construction safety hazards and accidents. *Automation in Construction*, 113: 103127. https://doi.org/10.1016/j.autcon.2020.103127

Lopes, J., Oliveira, R. and Abreu, M.I. (2017). The sustainability of the construction industry in Sub-saharan Africa: Some new evidence from recent data. *Procedia Engineering*, 172: 657–664. https://doi.org/10.1016/j.proeng.2017.02.077

Ma, J., Zhou, H., Liu, C., Mingcheng, E., Jiang, Z. and Wang, Q. (2020). Study on edge-cloud collaborative production scheduling based on enterprises with multi-factory. *IEEE Access*, 8: 30069–30080. https://doi.org/10.1109/ACCESS.2020.2972914

McNeish, D. (2018). Thanks coefficient alpha, we'll take it from here. *Psychological Methods*, 23(3): 412–433. https://doi.org/10.1037/met0000144

Mell, P. and Grance, T. (2011). The NIST definition of cloud computing: Recommendations of the National Institute of Standards and Technology. *NIST Special Publication 800-145*. https://doi.org/10.6028/NIST.SP.800-145

Mohd Fateh, M.A. and Nikmat, N.S. (2023). Common defects in public institutional buildings in Malaysia. *Journal of Sustainability Science and Management*, 18(7): 36–53. https://doi.org/10.46754/jssm.2023.07.003

Mohd Fateh, M.A. and Zamri, D.A. (2022). Challenges of working from home and the mitigation actions to overcome the challenges from the quantity surveyors'perspective. *Journal of Sustainability Science and Management*, 17(8): 144–164. https://doi.org/http://doi.org/10.46754/jssm.2022.08.009

Musarat, M.A., Alaloul, W.S. and Liew, M.S. (2021). Impact of inflation rate on construction projects budget: A review. *Ain Shams Engineering Journal*, 12(1): 407–414. https://doi.org/10.1016/j.asej.2020.04.009

Nagendra, S.V. and Rafi, N. (2018). Application of AI in construction project management. *International Journal of Research in Engineering*, *Science and Management*, 1(12): 423–427.

Oesterreich, T.D. and Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, 83: 121–139. https://doi.org/10.1016/j.compind.2016.09.006

Oke, A., Kineber, A., Albukhari, I., Othman, I. and Kingsley, C. (2021). Assessment of cloud computing success factors for sustainable construction industry: The case of Nigeria. *Buildings*, 11(2): 36. https://doi.org/10.3390/buildings11020036

Okereke, R.A., Ihekweme, N.M. and Adegboyega, M. (2022). Impact of traditional procurement system on construction project delivery. *Journal of Project Management Practice*, 2(2): 23–38. https://doi.org/10.22452/jpmp.vol2no2.2

Omar, F. and Mohd Fateh, M.A. (2023). Cost benefit analysis (CBA) in building information modelling (BIM) application in government healthcare facilities projects in Malaysia. *Planning Malaysia*, 21(2): 25–39. https://doi.org/10.21837/pm.v21i26.1257

Onungwa, I., Olugu-Uduma, N. and Shelden, D.R. (2021). Cloud BIM technology as a means of collaboration and project integration in smart cities. *SAGE Open*, 11(3). https://doi.org/10.1177/21582440211033250

Opeyemi, I.L., Ogunnubi, T., Orimoloye, M., Abraham, A. and Ukwunna, C. (2019). Project scheduling tools and techniques for effective construction management. *Advances in Multidisciplinary and Scientific Research Journal Publication*, 15(1): 321–338. https://doi.org/10.22624/AIMS/iSTEAMS-2019/V15N1P30

Oraee, M., Hosseini, M.R., Edwards, D.J., Li, H., Papadonikolaki, E. and Cao, D. (2019). Collaboration barriers in BIM-based construction networks: A conceptual model. *International Journal of Project Management*, 37(6): 839–854. https://doi.org/10.1016/j.ijproman.2019.05.004

Phillips-Wren, G. and McKniff, S. (2020). Overcoming resistance to big data and operational changes through interactive data visualization. *Big Data*, 8(6): 528–539. https://doi.org/10.1089/big.2020.0056

Rashidi, A. and Ibrahim, R. (2017). Industrialized construction chronology: The disputes and success factors for a resilient construction industry in Malaysia. *The Open Construction and Building Technology Journal*, 11. https://doi.org/10.2174/1874836801711010286

Shamim, M. (2022). Information security: The landscape of management in electronic record. *Proceedings of the International Seminar on Business, Education and Science*, 1(1): 336–348. https://doi.org/10.29407/int.v1i1.2689

Sharma, T.K. and Saini, H. (2019). State of art on efficient document co-editing in cloud collaboration. *International Journal of Spatio-Temporal Data Science*, 1(1): 114. https://doi.org/10.1504/IJSTDS.2019.097604

Shila, M., Jayanti, S. and Bibhav, A. (2023). Reliability analysis of a self-developed elderly well-being scale. *International Journal of Health Sciences and Research*, 13(2): 69–75. https://doi.org/10.52403/ijhsr.20230211

Smith, P. (2014). Project cost management: Global issues and challenges. *Procedia – Social and Behavioral Sciences*, 119: 485–494. https://doi.org/10.1016/j.sbspro.2014.03.054

Soto, B.G.D., Agustí-Juan, I., Joss, S. and Hunhevicz, J. (2019). Implications of Construction 4.0 to the workforce and organizational structures. *International Journal of Construction Management*, 22(2): 205–217. https://doi.org/10.1080/15623599.2019.1616414

Srivastava, Y.C., Srivastava, A., Granata, C. and Garg, T. (2022). Digital control tower: Instantaneous visibility, granularity and decision support for an LNG mega project. Paper presented at the ADIPEC. Abu Dhabi, UAE, 31 October–3 November. https://doi.org/10.2118/211056-MS

Subramanian, G., Patil, B.T. and Gardas, B.B. (2021). Evaluation of enablers of cloud technology to boost industry 4.0 adoption in the manufacturing micro, small and medium enterprises. *Journal of Modelling in Management*, 16(3): 944–962. https://doi.org/10.1108/JM2-08-2020-0207

Sukiman, M.A. (2020). The critical success factors of cloud based application implementation in construction management. Master's diss. University of Malaya.

Tahir, M.M., Haron, N.A., Alias, A.H., Harun, A.N., Muhammad, I.B. and Baba, D.L. (2018). Improving cost and time control in construction using building information model (BIM): A review. *Pertanika Journal of Science and Technology*, 26(1): 21–36.

Tao, J., Marten, H., Kramer, D. and Karl, W. (2011). An intuitive framework for accessing computing clouds. *Procedia Computer Science*, 4: 2049–2057. https://doi.org/10.1016/j.procs.2011.04.224

Walker, D.H.T., Davis, P.R. and Stevenson, A. (2017). Coping with uncertainty and ambiguity through team collaboration in infrastructure projects. *International Journal of Project Management*, 35(2): 180–190. https://doi.org/10.1016/j.ijproman.2016.11.001

Wong, J., Wang, X., Li, H., Chan, G. and Li, H. (2014). A review of cloud-based BIM technology in the construction sector. *Journal of Information Technology in Construction*, 19(August): 281–291.

Wood, D.J. and Gray, B. (1991). Toward a comprehensive theory of collaboration. *The Journal of Applied Behavioral Science*, 27(2): 139–162. https://doi.org/10.1177/0021886391272001

Wood, L. (2020). $90.6 billion worldwide precast construction industry to 2027: Impact of COVID-19 on the Market. *Research and Markets*, 20 November. Available at: https://www.globenewswire.com/fr/news-release/2020/11/20/2130948/28124/en/90-6-Billion-Worldwide-Precast-Construction-Industry-to-2027-Impact-of-COVID-19-on-the-Market.html

Yap, J.B.H., Abdul-Rahman, H. and Chen, W. (2017). Collaborative model: Managing design changes with reusable project experiences through project learning and effective communication. *International Journal of Project Management*, 35(7): 1253–1271. https://doi.org/10.1016/J.IJPROMAN.2017.04.010

Zhang, L., Cao, T. and Wang, Y. (2018). The mediation role of leadership styles in integrated project collaboration: An emotional intelligence perspective. *International Journal of Project Management*, 36(2): 317–330. https://doi.org/10.1016/j.ijproman.2017.08.014

Zhang, N., Hwang, B.-G., Deng, X. and Tay, F. (2022). Exploring critical success factors for collaborative contracting implementation in the Singapore construction industry. *Engineering*, *Construction and Architectural Management*, Forthcoming. https://doi.org/10.1108/ECAM-05-2022-0398

Zuhairi, A.N.F.A., Mohd Fateh, M.A. and Hong, W.T. (2022). Enhancing leadership behaviour to improve employee motivation during the COVID-19 pandemic. *Malaysian Construction Research Journal*, 17(3): 209–227.

Zuhairy, M., Iberahim, H. and Ismail, N. (2015). Relationship between innovation and organizational performance in construction industry in Malaysia. *Universal Journal of Industrial and Business Management*, 3(4): 87–99. https://doi.org/10.13189/ujibm.2015.030402