Success Factors for Implementing Cloud-Based Construction Management Software (CBCMS) in Malaysia's Construction Projects

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DOI: https://doi.org/10.47772/IJRISS.2026.101000750

Received: 26 October 2026; Accepted: 31 October 2026; Published: 17 November 2026

ABSTRACT

Cloud-Based Construction Management Software (CBCMS) supports construction project management through centralised data management, real-time collaboration and improved project transparency. This study aimed to identify the key success factors for CBCMS implementation in Malaysian construction projects and to evaluate practitioners' perceptions of the importance of these factors for effective implementation. A quantitative cross-sectional survey was conducted using a structured questionnaire comprising 30 five-point Likert-scale items across six literature-derived criteria. The instrument was content-validated by three academic experts and pilot-tested with 30 respondents. Empirical responses from 130 practitioners, purposively sampled from G7 contractor companies registered with the Construction Industry Development Board (CIDB) Malaysia, were analysed using mean scores, Relative Importance Index (RII), item-rest correlations, Cronbach's alpha, Repeated-Measures ANOVA, Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA) and multiple linear regression in Jamovi. All six criteria exhibited high internal consistency ($\alpha = 0.896–0.916$) and high levels of practitioner agreement (means = 4.26–4.32; RII = 0.851–0.865). Functionality was ranked highest (mean = 4.32, RII = 0.865), with integration with Building Information Modelling (BIM) and other software being its highest-rated item (mean = 4.38), followed by project performance impact (mean = 4.30, RII = 0.859). EFA and CFA showed that the items loaded strongly on their constructs (CR = 0.896–0.915; AVE = 0.632–0.684), but the six criteria were highly intercorrelated (HTMT up to 0.994), indicating related dimensions of one overall construct. Repeated-Measures ANOVA indicated that differences among criteria means were not statistically significant ($F = 1.117$, $p = 0.348$). Furthermore, multiple linear regression ($R^2 = 0.884$, $p < 0.001$) showed that functionality, usability, data management and security, and organisational support were significantly and positively associated with perceived project performance impact. These findings, which reflect predominantly large-contractor perspectives, provide practical guidance for contracting organisations modernising digital construction workflows in Malaysia.

Keywords: Cloud-based construction management software, Critical success factors, Building Information Modelling (BIM), Relative Importance Index, Malaysia

INTRODUCTION

The construction industry involves multiple stakeholders, complex project activities, and continuous exchanges of information throughout the project lifecycle. Project information may involve drawings, schedules, cost information, requests for information, approvals, progress reports, and contractual documentation. When this information is managed through fragmented or conventional systems, project teams may experience communication delays, inconsistent documents, duplication of work and difficulties in obtaining current information. Cloud-based and web-based construction technologies have therefore become increasingly relevant because they facilitate information sharing, document management, communication and collaboration among geographically distributed project participants (Bello et al., 2021; Chowdhury et al., 2021).

Digital transformation has also become increasingly important in the Malaysian construction industry through the adoption of technologies associated with Construction 4.0, including Building Information Modelling (BIM), the Internet of Things (IoT), cloud computing and digital project-management platforms. Nevertheless, technology implementation in the Malaysian construction sector continues to be affected by organisational, technological and human-related barriers. Previous Malaysian studies identified issues such as limited awareness, connectivity, security concerns, insufficient technological readiness, and difficulties in changing traditional working practices (Gamil et al., 2020; Jaafar et al., 2026).

Cloud-Based Construction Management Software (CBCMS) represents one approach to addressing these problems by providing a central online environment in which project teams can store, retrieve, update, and communicate project information. Cloud technologies have been found to improve access to project information, collaboration, monitoring and management efficiency, while potentially reducing project delays. However, the availability of software itself does not guarantee successful implementation because user competence, management support, training, security, compatibility, and system functionality can influence how effectively a digital platform is used (Musarat et al., 2024; Won et al., 2022; Mohd Fateh et al., 2024).

Previous studies have investigated cloud computing, BIM, real-time collaboration, and technology adoption in construction; however, limited empirical attention has been given specifically to the combination of success factors required for CBCMS implementation within Malaysian construction projects. Research on cloud-based construction systems suggests that both technological capabilities and non-technological conditions must be considered because collaboration, organisational readiness, user acceptance, and information security collectively influence digital implementation (Bello et al., 2021; Onungwa et al., 2021; Mohd Fateh et al., 2024). Existing studies of success factors for cloud-based project management tools have largely been conducted in other sectors or national contexts, such as the software development industry (Assalaarachchi et al., 2022, 2025) and the construction industries of Nigeria (Oke et al., 2021) and Singapore (Won et al., 2022), so their findings cannot be assumed to transfer directly to Malaysian construction projects.

Accordingly, this study has two objectives: (1) to identify the key success factors for implementing cloud-based construction management software in Malaysia’s construction projects; and (2) to evaluate construction industry practitioners' perceptions of the relative importance of these factors for effective cloud-based construction management software implementation in Malaysia. To address the second objective, the study also examines the factor structure of the instrument, tests whether the differences in perceived importance between the criteria are statistically significant and examines how the criteria are associated with perceived project performance impact. Because all measures are practitioners' perceptions collected at a single point in time, these associations are not interpreted as causal effects.

This study makes three contributions. First, it consolidates technological, user-related and organisational success factors for CBCMS into a six-criterion measurement instrument whose reliability and factor structure are examined. Second, it provides empirical evidence on the relative importance that Malaysian construction practitioners assign to these factors, a context that has received limited attention in previous cloud computing research. Third, it translates the findings into practical guidance for construction organisations planning or improving CBCMS implementation.

The remainder of this paper is organised as follows. The next section reviews the literature on CBCMS and its success factors. The research methodology is then described, followed by the results and discussion. The final section presents the conclusions, limitations and directions for future research.

LITERATURE REVIEW

CBCMS refers to cloud-based digital platforms that enable construction project information and management activities to be accessed through internet-connected devices. Such platforms may support document control, drawing management, version control, requests for information, submittals, site reporting, progress monitoring, scheduling, cost management, issue tracking, approvals, and communication.

CBMS and digital construction

Cloud computing provides the underlying infrastructure through which construction information can be centrally managed and made available to multiple stakeholders, thereby improving accessibility and information exchange across project teams (Bello et al., 2021; Musarat et al., 2024).

A major advantage of CBCMS is the ability to create a more integrated project-information environment. Instead of exchanging files individually through email or relying on separate paper records, stakeholders can access shared documents and project updates through a common platform. Cloud BIM research has similarly shown that digital platforms can facilitate data exchange, visualisation, project integration and real-time collaboration among project participants. Web-based collaboration platforms have also been found to improve coordination by providing common information-sharing and workflow-management mechanisms (Onungwa et al., 2021; Chowdhury et al., 2021).

Nevertheless, cloud-based implementation presents several challenges. Organisations may face resistance to change, inadequate user competency, limited training, weak internet connectivity, software integration problems, implementation costs, and concerns regarding cybersecurity. These issues indicate that CBCMS implementation should not be evaluated only according to the technical availability of a platform. Organisational preparedness, user capabilities, security governance, and continuous support are also necessary to achieve sustainable use (Gamil et al., 2020; Tanga et al., 2022; Mohd Fateh et al., 2024).

From a theoretical perspective, the adoption of cloud-based technologies is frequently examined through the Technology–Organisation–Environment (TOE) framework, which recognises that adoption is shaped jointly by technological characteristics, organisational conditions and the external environment (Al Hadwer et al., 2021). Survey evidence on organisational cloud adoption similarly indicates that adoption depends on a combination of technological and organisational factors (Stieninger et al., 2018). Comparable multidimensional perspectives have been applied to BIM, where technology, process and people-related conditions together determine implementation outcomes (Succar, 2009; Gu & London, 2010). These perspectives inform the six criteria adopted in this study, which combine technology-related factors (usability, functionality, and data management and security), organisational factors (organisational support, training and costs) and project-related factors (collaboration and project performance impact).

The study is also consistent with project-management principles described in the PMBOK Guide, particularly stakeholder engagement, project work, planning, delivery, measurement, and uncertainty management. CBCMS provides digital tools that can support these project-management activities by facilitating project coordination, communication, documentation and monitoring. ISO 21502:2020 similarly emphasises project governance, planning, monitoring, stakeholder engagement and delivery, while ISO/IEC 27001:2022 provides relevant principles regarding confidentiality, integrity, availability, access control and information-security risk management (Project Management Institute, 2021; International Organization for Standardization, 2020, 2022).

Key success factors for CBCMS implementation

Based on the literature review, successful CBCMS implementation depends on several technical, organisational and user-related factors. Six main criteria were identified in this study: usability; functionality; collaboration,

communication and stakeholder engagement; project performance impact; data management and security; and organisational support, training and costs. These factors were selected because effective implementation requires not only a capable digital platform, but also user acceptance, secure information management, effective collaboration and sufficient organisational support (Mohd Fateh et al., 2024; Onungwa et al., 2021; Maali et al., 2020). Synthesis of empirical and theoretical literature revealed six core dimensions that dictate successful CBCMS implementation:

1. Usability: Encompasses intuitive interface design, logical navigation hierarchies, field mobile accessibility, and low cognitive learning barriers. High usability accelerates software adoption across construction teams characterized by heterogeneous digital proficiencies (Bello et al., 2021; Mohd Fateh et al., 2024).
2. Functionality: Refers to the technical competence and breadth of the software in executing vital construction workflows, automated document tracking, real-time revision notifications, system reliability, and crucially, interoperability with BIM authoring tools and enterprise scheduling software (Onungwa et al., 2021; Musarat et al., 2024).
3. Collaboration, Communication and Stakeholder Engagement: Represents the ability of the platform to centralize multi-stakeholder interactions, streamline RFI turnarounds, clarify decision histories, and eliminate information asymmetries among clients, consultants, main contractors, and subcontractors (Chowdhury et al., 2021; Yap & Oo, 2025).
4. Project Performance Impact: Evaluates the concrete contributions of CBCMS to project schedule adherence, delay mitigation, quality assurance, milestone tracking, cost control, and efficient project closeout/handover documentation (Musarat et al., 2024; Waqar et al., 2023).
5. Data Management and Security: Pertains to reliable cloud storage, automated backup redundancies, granular role-based access permissions, confidential commercial data protection, and trustworthy analytics reporting in accordance with ISO/IEC 27001 (Tanga et al., 2022; Jaskula et al., 2024).
6. Organisational Support, Training and Costs: Encompasses executive leadership commitment, sufficient budget allocation for recurring software licensing and hardware provisioning, comprehensive onboarding and upskilling programs, and mechanisms for continuous system optimization (Maali et al., 2020; Mohd Fateh et al., 2024).

RESEARCH METHODOLOGY

This section describes the methodology used to investigate the success factors for implementing CBCMS in Malaysian construction projects. A quantitative survey approach was adopted to collect numerical data from construction practitioners. The methodology covered questionnaire development, expert validation, pilot testing, purposive sampling, data collection, and statistical analysis using mean scores, the relative importance index (RII), item-rest correlation, Cronbach's alpha, factor analysis, repeated-measures ANOVA and multiple linear regression to ensure that the findings were reliable and aligned with the research objectives (Yusoff et al., 2021; Jebb et al., 2021).

Research design and sampling

A quantitative cross-sectional research design was employed because the study aimed to obtain numerical assessments of practitioners' perceptions of CBCMS implementation factors. A structured questionnaire enabled the respondents' level of agreement to be measured systematically and analysed using descriptive, reliability, factor-analytic and inferential statistics. Five-point Likert scales are widely used for measuring attitudes, perceptions and levels of agreement in questionnaire-based research, making this approach suitable for the research objectives (Jebb et al., 2021).

The sampling frame comprised 185 G7 contractor companies identified from the Construction Industry Development Board Malaysia (CIDB) listing. Purposive sampling was adopted to target respondents with relevant construction-industry involvement and knowledge of CBCMS. Purposive sampling is appropriate where participants are selected because their knowledge, experience, or involvement is particularly relevant to the research subject (Campbell et al., 2020). The minimum sample size calculated using the Raosoft calculator was 126 respondents (population of 185, 5% margin of error, 95% confidence level and 50% response distribution),

while the final survey obtained 130 completed responses. Because the sampling frame consisted only of G7 contractor companies, the sample mainly represents the perspective of large contractor organisations.

Questionnaire development

The questionnaire was developed based on the research objectives and success factors identified from the literature. It consisted of four sections. Section A contained six questions concerning respondent demographics and CBCMS exposure. Section B contained six questions relating to platform usage. Section C contained 30 five-point Likert-scale items covering the six success-factor criteria, with five items for each criterion. Section D provided one open-ended question for additional recommendations, resulting in a total of 43 questionnaire items. Questionnaire construction based on clearly defined research constructs improves the alignment between the instrument and the intended variables of a study (Yusoff et al., 2021). The summary of the measurement criteria for CBCMS implementation is presented in Table 1.

Table 1: Measurement criteria for CBCMS implementation

Criterion	Code	Main measurement focus	Items
Usability	U1 - U5	Ease of use, navigation, mobile access, and work efficiency	5
Functionality	F6 - F10	Construction workflows, software integration, file management, notifications and reliability	5
Collaboration, communication and stakeholder engagement	CC11 - CC15	Information sharing, teamwork, communication, feedback and approvals	5
Project performance impact	PP16 - PP20	Milestones, efficiency, quality, timely delivery, delay reduction and handover	5
Data management and security	DM21 - DM25	Storage, backup, sensitive information, access control and reporting	5
Organisational support, training and costs	OS26 - OS30	Training, technical support, management encouragement, cost and continuous improvement	5

Content and face validity were verified prior to deployment through rigorous review by three senior academic experts specializing in construction informatics. Modifications were incorporated to refine terminology, eliminate ambiguous phrasing, and ensure construct uniqueness (Yusoff et al., 2021). A pilot test was administered to 30 construction practitioners and produced Cronbach's alpha values ranging from 0.732 to 0.896 across the six criteria (overall $\alpha = 0.889$), indicating acceptable to good initial internal consistency (Bujang et al., 2024; Haji-Othman et al., 2021).

Data collection

The final questionnaire was distributed electronically using Google Forms through email, and responses were collected between 07th May 2026 to 25th May 2026. Online distribution enabled responses to be obtained from relevant practitioners efficiently while retaining the same structured questionnaire for all participants. Participants were informed about the purpose of the study, participation was voluntary, and confidentiality and anonymity were maintained throughout data collection and reporting, consistent with ethical considerations relevant to electronic survey research (Harris et al., 2024; Xu et al., 2020).

Data analytical framework and statistical procedures

Data analysis was performed using Microsoft Excel and Jamovi statistical software. To address the specific methodological requirements of robust survey research and reviewer recommendations, a multi-tiered analytical strategy was implemented:

1. Descriptive & Prioritization Metrics (Mean, SD, and RII): To express the importance of each criterion and item on a standardised 0–1 index widely used in construction management research (Holt, 2014), the Relative Importance Index (RII) was computed for each construct and item. The RII formula applied was:

   $$RII = \sum W / (A \times N)$$

   where W represents the weight assigned to each factor by respondents (from 1 to 5), A is the highest weight (A = 5), and N is the total sample size (N = 130). RII scores range between 0 and 1, with higher values reflecting greater perceived priority. For a five-point scale, RII equals the mean divided by five, so it confirms the ranking but cannot by itself show whether the criteria differ significantly.

2. Construct Validity and Structural Factor Analysis: To rigorously test whether Cronbach's alpha values exceeding 0.90 indicated problematic item redundancy or severe multicollinearity, an Exploratory Factor Analysis (EFA) utilizing Principal Axis Factoring with Promax oblique rotation was performed. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were evaluated to confirm factorability. The number of factors was assessed using eigenvalues and parallel analysis. A Confirmatory Factor Analysis (CFA) of the hypothesised six-factor model was then estimated by maximum likelihood and compared with a single-factor model, with fit judged by CFI and TLI (≥ 0.90), RMSEA and SRMR (≤ 0.08) (Hu & Bentler, 1999). Convergent validity was assessed through composite reliability (CR ≥ 0.70) and average variance extracted (AVE ≥ 0.50), and discriminant validity through the Fornell–Larcker criterion and heterotrait–monotrait (HTMT) ratios below 0.90 (Fornell & Larcker, 1981; Henseler et al., 2015). Harman's single-factor test was used to check for common method variance (Podsakoff et al., 2003). Item-rest correlations (corrected item-total correlations) were also assessed against the established 0.30 cutoff threshold (Kaiser, 1974; Cheung et al., 2024; Yusoff et al., 2021; Singh et al., 2021; Chang et al., 2021).

3. Inferential Comparative and Predictive Modelling: A Repeated-Measures Analysis of Variance (ANOVA) with Greenhouse–Geisser correction (Greenhouse & Geisser, 1959), with a Friedman test as a non-parametric check, was conducted to establish whether numerical differences across the six criteria ratings were statistically significant. Furthermore, to move beyond descriptive reporting and examine associations between the success factors and perceived project performance, a Multiple Linear Regression model was established. Functionality, Usability, Data Management & Security, Collaboration & Communication, and Organisational Support & Training were entered as independent predictor variables, with Project Performance Impact operationalised as the dependent variable. Multicollinearity was assessed using variance inflation factors (VIF) (Kock, 2015; Hair et al., 2019).

RESULTS AND DISCUSSION

This section outlines the empirical findings derived from the 130 validated responses, detailing respondent profiles, factor structure validation, RII prioritization, comparative significance, predictive regression modelling, and contextual discussion.

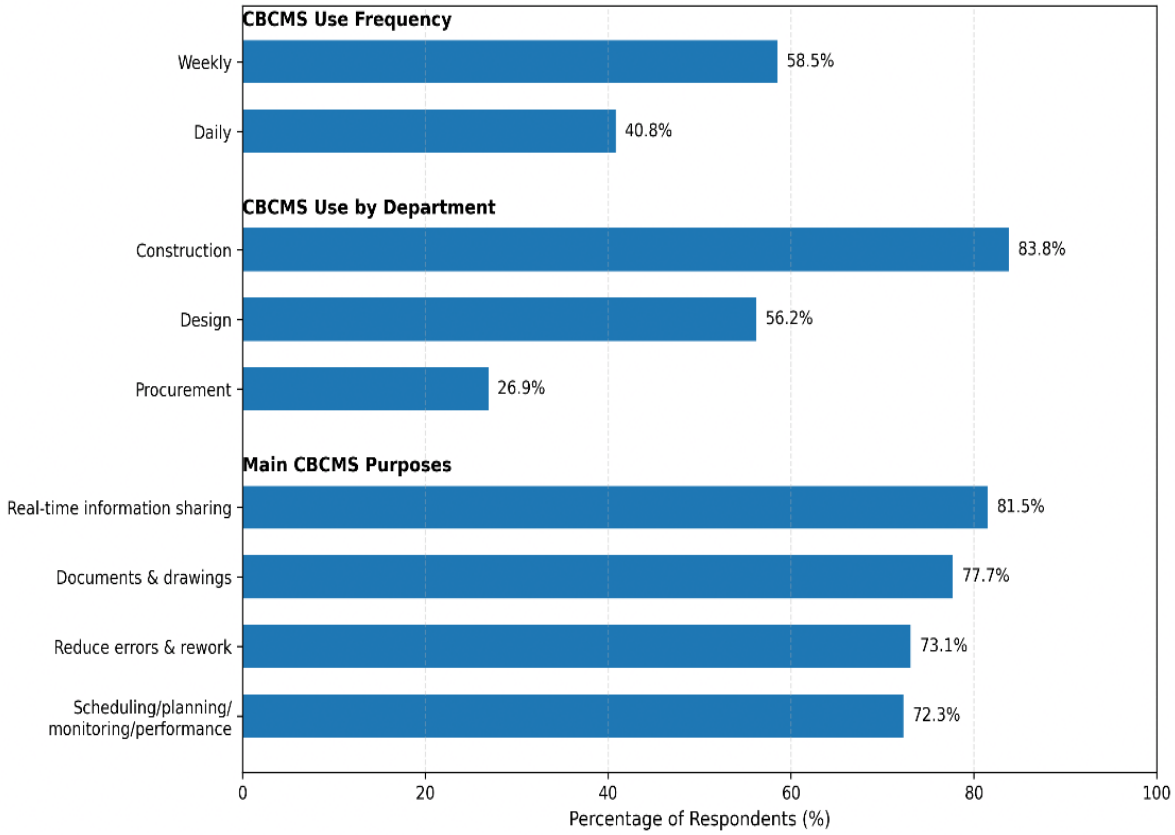
Profile of respondents and CBCMS utilization patterns

A total of 130 valid responses were obtained. Male respondents accounted for 81.5% of the sample, while 18.5% were female. Almost half of the respondents, 49.2%, had between five and ten years of construction-industry experience. Engineers represented the largest professional group at 20.8%, followed by architects at 18.5% and assistant engineers at 15.4%. Contractors represented 96.2% of the organisation types, reflecting the study's purposive sampling focus on G7 contractor companies. The remaining 3.8% were developers. The concentration of experienced construction practitioners provided a relevant respondent base for assessing construction digitalisation and CBCMS implementation (Campbell et al., 2020).

Based on Figure 1, most respondents had previous exposure to cloud-based construction platforms, with 83.8% reporting that they were aware of or had used CBCMS before. Of the 110 respondents who answered the specific platform-use question (multiple responses were permitted), Autodesk Construction Cloud was the most frequently reported platform at 71.8%, followed by Procore at 26.4% and Oracle Primavera Cloud at 5.5%. The relatively high level of prior CBCMS exposure was important because perceptions of digital systems become more meaningful when practitioners have practical contact with construction information-management and collaboration platforms (Bello et al., 2021; Mohd Fateh et al., 2024).

CBCMS was also used frequently by respondents, with 58.5% reporting weekly use and 40.8% reporting daily use. Construction departments recorded the highest reported use at 83.8%, followed by design at 56.2% and procurement at 26.9% (multiple responses were permitted). The main purposes reported were sharing information in real time between stakeholders (81.5%), handling project documents and drawings (77.7%), reducing errors and rework (73.1%), and supporting scheduling, planning, monitoring, and performance tracking (72.3%). These uses correspond closely with previous findings that cloud construction platforms are particularly valuable for information exchange, project coordination, and real-time collaboration (Onungwa et al., 2021; Chowdhury et al., 2021).

Figure 1: CBCMS usage patterns, departmental adoption and main purposes



Factorial structure and construct validity analysis

To address concerns regarding potential item redundancy stemming from elevated reliability coefficients (α = 0.896–0.916), structural validity was examined through Exploratory and Confirmatory Factor Analysis. The Kaiser-Meyer-Olkin (KMO) measure was 0.952, well above the recommended 0.80 benchmark, demonstrating excellent sampling adequacy. Bartlett's Test of Sphericity yielded a highly significant result (χ^2 = 3729.59, df = 435, $p < 0.001$), rejecting the identity matrix hypothesis and confirming suitable correlation structures for factor extraction.

Principal axis factoring revealed one dominant factor: the first eigenvalue was 18.91, explaining 63.0% of the total variance, whereas the second was 1.12 (3.7%) and all remaining eigenvalues were below 1.0. Parallel

analysis supported retaining a single factor, on which all 30 items loaded strongly (0.745–0.827). When six factors were extracted with Promax rotation, the items did not separate cleanly into the six hypothesised criteria. Item-rest correlations ranged from 0.709 to 0.806, substantially exceeding the 0.30 psychometric threshold, and the highest inter-item correlation within any construct was 0.769, below 0.80.

The CFA of the hypothesised six-factor model showed acceptable fit ($\chi^2(390) = 686.24$, $\chi^2/df = 1.76$, CFI = 0.919, TLI = 0.910, RMSEA = 0.077, SRMR = 0.059) and fitted significantly better than a single-factor model ($\Delta\chi^2(15) = 161.60$, $p < 0.001$). Standardised loadings ranged from 0.775 to 0.852, CR from 0.896 to 0.915 and AVE from 0.632 to 0.684, supporting convergent validity. However, discriminant validity was not established: the latent correlations between constructs (0.856–0.996) exceeded the square root of each construct's AVE (0.795–0.827), and 11 of the 15 HTMT ratios exceeded 0.90, with the highest overlap between functionality and project performance impact (r = 0.996).

These results indicate that the high alpha values do not reflect duplicated items within constructs, but that the six criteria are strongly interrelated dimensions of a broader perception of CBCMS implementation success rather than fully independent factors. This is consistent with the narrow range of mean scores and with the multidimensional view of technology adoption in the TOE framework (Al Hadwer et al., 2021).

Prioritization and ranking of CBCMS success factors

To express the importance of the six dimensions on a standardised index, the Relative Importance Index (RII) was calculated alongside mean and reliability scores. Table 2 presents the consolidated ranking, descriptive parameters, RII scores, and reliability coefficients.

Table 2: Overall ranking, reliability, and Relative Importance Index (RII) of CBCMS success factors (N = 130)

Rank	Success factor	Overall mean	SD	RII	Cronbach's α	Item-Rest Range
1	Functionality	4.32	0.61	0.865	0.916	0.768 – 0.799
2	Project performance impact	4.3	0.59	0.859	0.896	0.709 – 0.764
3	Organisational support, training and costs	4.29	0.6	0.858	0.914	0.769 – 0.806
4	Usability	4.29	0.6	0.857	0.901	0.716 – 0.769
5	Data management and security	4.28	0.6	0.855	0.908	0.752 – 0.794
6	Collaboration, communication and stakeholder engagement	4.26	0.62	0.851	0.912	0.746 – 0.797

As presented in Table 2, Functionality emerged as the highest-priority dimension (Mean = 4.32, RII = 0.865), closely followed by Project Performance Impact (Mean = 4.30, RII = 0.859) and Organisational Support, Training and Costs (Mean = 4.29, RII = 0.858). Usability and Data Management & Security ranked fourth and fifth (Mean = 4.29 and 4.28; RII = 0.857 and 0.855), while Collaboration, Communication and Stakeholder Engagement occupied the sixth position (Mean = 4.26, RII = 0.851).

To test whether the differences between the tightly grouped mean ratings were statistically significant, a Repeated-Measures ANOVA was executed. Mauchly's test indicated that the assumption of sphericity was violated (W = 0.617, $p < 0.001$); therefore, the Greenhouse-Geisser correction was applied ($\varepsilon = 0.839$). The resulting ANOVA test yielded $F(4.20, 541.25) = 1.117$, $p = 0.348$ (partial $\eta^2 = 0.009$), and the Friedman test gave the same result ($\chi^2(5) = 3.87$, $p = 0.569$, Kendall's W = 0.006). Because $p > 0.05$, the differences between the six criteria are not statistically significant.

This result indicates that respondents did not distinguish meaningfully between the six criteria. A non-significant result does not prove that the criteria are equally important, but together with the very small effect size it shows that the ranking in Table 2 should be read as indicative rather than as a strict order of priority. A plausible interpretation is that G7 contractors regard CBCMS implementation as an interdependent socio-technical system, in which functionality cannot be separated from usability, and collaboration depends on reliable data governance and organisational support (Al Hadwer et al., 2021; Mohd Fateh et al., 2024).

Table 3 displays the top-rated individual items within each criterion, illustrating the specific operational capabilities prioritized by industry practitioners.

Table 3: Highest-rated items within each CBCMS criterion

Criterion	Highest-rated item	Mean	RII
Usability	U1 - The platform has an intuitive and user-friendly interface	4.32	0.865
Functionality	F7 - The system can integrate with BIM and other software	4.38	0.877
Collaboration, communication and stakeholder engagement	CC14 - The platform reduces problems caused by poor communication	4.32	0.863
Project performance impact	PP19 - The platform helps deliver projects on time and reduce delays	4.38	0.875
Data management and security	DM23 - Access is controlled based on user roles and permissions	4.32	0.863
	DM25 - Data analytics and reports are accurate and trustworthy	4.32	0.863
Organisational support, training and costs	OS30 - Continuous improvement is supported through feedback and updates	4.33	0.866

Inferential predictive modeling: Multiple linear regression

To examine how the implementation dimensions are associated with perceived project delivery outcomes, multiple linear regression analysis was performed. In this model, Project Performance Impact (representing time savings, schedule delay mitigation, quality control, and handover efficiency) served as the dependent variable, while the remaining five criteria were entered as independent predictors. Table 4 presents the model estimation results.

Table 4: Multiple linear regression analysis predicting Project Performance Impact

Model Predictors	Unstand. B	Std. Error	Stand. β	t-value	p-value	Collinearity (VIF)
(Intercept)	0.135	0.138	—	0.978	0.330	—
Functionality (F)	0.406	0.067	0.422	6.094	< 0.001*	5.11
Usability (U)	0.315	0.064	0.323	4.896	< 0.001*	4.63
Data Management & Security (DM)	0.186	0.071	0.189	2.607	0.010*	5.61
Organisational Support & Costs (OS)	0.182	0.069	0.186	2.632	0.010*	5.34
Collaboration & Communication (CC)	−0.123	0.060	−0.130	−2.047	0.043*	4.31

*Note: Dependent Variable = Project Performance Impact. Model Fit: $R = 0.940$, $R^2 = 0.884$, Adjusted $R^2 = 0.879$, $F(5, 124) = 188.41$, $p < 0.001$. *Statistically significant at $p < 0.05$.*

The overall regression model was statistically significant ($F(5, 124) = 188.41$, $p < 0.001$), explaining 88.4% of the variance in Project Performance Impact ($R^2 = 0.884$, Adjusted $R^2 = 0.879$). VIF values ranged from 4.31 to

5.61, above the conservative threshold of 3.3 (Kock, 2015) but below the commonly used limit of 10 (Hair et al., 2019). Given this overlap and the limited discriminant validity reported above, the high R^2 largely reflects the shared variance among the criteria, and individual coefficients should be interpreted with caution; when the model was re-estimated as a latent-variable SEM, only functionality and usability remained significant. Four of the five predictor dimensions were significantly and positively associated with perceived project performance:

1. Functionality proved to be the strongest individual predictor ($\beta = 0.422$, $t = 6.094$, $p < 0.001$). This suggests that digital tool features, particularly BIM integration and workflow management, have the strongest association with perceived project efficiencies.
2. Usability was also significantly and positively associated with perceived project performance ($\beta = 0.323$, $t = 4.896$, $p < 0.001$). Intuitive interfaces may help field teams record and update progress promptly, reducing data backlogs and site misalignments.
3. Data Management and Security was also significantly associated with perceived performance ($\beta = 0.189$, $t = 2.607$, $p = 0.010$). Role-based governance and traceable documentation can provide a verifiable data baseline that supports dispute prevention and accurate milestone billing.
4. Organisational Support and Training showed a significant positive association ($\beta = 0.186$, $t = 2.632$, $p = 0.010$). Institutional change management and ongoing upskilling help ensure that software features are actively used rather than abandoned.
5. Interestingly, Collaboration, Communication and Stakeholder Engagement had a small negative coefficient in the multivariable model ($\beta = -0.130$, $t = -2.047$, $p = 0.043$), even though it correlated strongly and positively with project performance impact ($r = 0.775$). While communication is acknowledged as an indispensable project prerequisite (reflected in its high descriptive mean of 4.26), this sign reversal is typical of a suppression effect caused by the strong correlations among predictors, and indicates that collaboration adds no unique positive explanatory power once the other criteria are controlled. It should not be read as collaboration reducing performance; rather, communicating via the cloud is unlikely to improve performance on its own unless workflows, information accountability and technical integration are also well structured.

Detailed dimensional discussion

Functionality: Functionality achieved the highest RII (0.865) and strongest regression coefficient ($\beta = 0.422$). Individual item F7 ('The system can integrate with BIM and other software') recorded a top score of 4.38 (RII = 0.877). This suggests that contractors expect CBCMS to do more than store and share files. As BIM implementation expands in Malaysia (Othman et al., 2021), contractors are likely to expect two-way interoperability between cloud management systems (e.g., Autodesk Construction Cloud) and BIM authoring tools. Data synchronisation can reduce manual re-entry and drawing discrepancies between site and office, consistent with findings by Onungwa et al. (2021) and Bello et al. (2021).

Project Performance Impact: Ranked second overall (RII = 0.859), item PP19 ('The platform helps deliver projects on time and reduce delays') achieved a peak mean of 4.38 (RII = 0.875). For contractors, liquidated and ascertained damages (LAD) represent a significant financial risk. Cloud systems streamline inspection requests, accelerate RFI responses, and provide live dashboard tracking, which may help reduce critical-path bottlenecks (Musarat et al., 2024; Waqar et al., 2023).

Organisational Support, Training and Costs: Ranking third (RII = 0.858), item OS30 ('Continuous improvement is supported through feedback and updates') recorded 4.33 (RII = 0.866). Software procurement is merely an initial milestone; sustaining long-term digital ROI requires structured executive backing, targeted technical coaching, and continuous system configuration adjustments. This reinforces Maali et al. (2020) and Mohd Fateh et al. (2024), who emphasised the importance of change management, leadership support and training for sustained technology adoption in construction organisations.

Usability: Usability ranked fourth (RII = 0.857), with item U1 ('Intuitive and user-friendly interface') scoring 4.32. Construction site environments involve high-stress operational conditions and varied technical competencies. A steep learning curve or complicated interface may cause resistance among site staff. Mobile-

friendly interfaces allow site staff to submit updates and access current drawings directly on site (Bello et al., 2021).

Data Management and Security: Ranked fifth (RII = 0.855), items DM23 (Role-based access permissions, 4.32) and DM25 (Trustworthy data analytics, 4.32) reflected practitioners' concern with data integrity. Commercial construction contracts involve confidential payment claims, unit rates, and variation disputes. Without rigorous role-based permission tiers and ISO/IEC 27001-compliant cybersecurity safeguards, contractors may be exposed to liability and the loss of commercially sensitive information (Tanga et al., 2022; Jaskula et al., 2024).

Collaboration and Communication: While ranking sixth (RII = 0.851), item CC14 ('Reduces problems caused by poor communication') received strong agreement (4.32). Centralizing transmittals inside a cloud CDE creates a traceable audit trail that can reduce the 'silent failures' and conflicting verbal instructions that historically trigger contractual claims (Yap & Oo, 2025; Chowdhury et al., 2021).

Contextual re-framing: The contractor-centric reality

An important consideration in interpreting these findings is the sample composition: 96.2% of respondents represented CIDB Grade 7 contractor firms. While this sample profile was purposively selected to represent large-scale builders managing complex, high-value projects, it imparts a distinct operational perspective that shapes the study's conclusions. For main contractors, project success depends largely on operational coordination, subcontractor control, physical schedule adherence, and contractual compliance under strict LAD provisions.

This perspective is consistent with Functionality (BIM interoperability) and Project Performance Impact (delay reduction) receiving the highest RII values, although the differences were not statistically significant; technical errors and schedule slippages directly affect contractor profit margins. Client organisations and design consultants may weigh the criteria differently, for example by placing more emphasis on life-cycle costs and statutory compliance; this expectation was not tested here and should be examined in future cross-stakeholder research. While the findings provide practical guidance for large commercial contractors transitioning into Construction 4.0, industry-wide digital adoption policies must harmonize these contractor-driven operational imperatives with client and consultant governance requirements.

Overall implications of the findings

Overall, the narrow mean range of 4.26–4.32, the non-significant ANOVA and the strong intercorrelations between criteria suggest that CBCMS success is multidimensional. Functionality received the highest rating, but its effectiveness depends on users being able to operate the system, organisations providing support, project information remaining secure, and project stakeholders communicating through the platform. This interaction between technical and organisational dimensions is consistent with research showing that construction technology adoption cannot be addressed solely through software capability (Maali et al., 2020; Mohd Fateh et al., 2024).

For construction organisations, the findings indicate that CBCMS selection should begin with an assessment of functional requirements, particularly integration with BIM and other applications. This should be followed by consideration of user experience, information governance, management commitment, training resources and stakeholder workflows. Such an implementation approach is consistent with project-management principles emphasising stakeholder engagement, governance, planning, delivery and continuous measurement (Project Management Institute, 2021; International Organization for Standardization, 2020).

From a theoretical perspective, the findings support multidimensional views of technology adoption, such as the TOE framework, in which technological capability alone is insufficient without supportive organisational conditions (Al Hadwer et al., 2021). The high rating given to integration with BIM and other software further suggests that CBCMS should be conceptualised as part of a broader BIM-enabled information-management environment rather than as a standalone application (Succar, 2009; Gu & London, 2010).

CONCLUSION

This study investigated the critical success factors governing Cloud-Based Construction Management Software (CBCMS) implementation within the Malaysian construction sector. Utilizing an empirical sample of 130 practitioners from CIDB G7 contractor firms, the research consolidated 30 measurement items across six dimensions: Functionality; Project Performance Impact; Organisational Support, Training and Costs; Usability; Data Management and Security; and Collaboration, Communication and Stakeholder Engagement. High internal consistency was confirmed across all constructs (α = 0.896–0.916), and factor analysis showed that the six criteria are coherent but highly interrelated dimensions of a broader construct, with limited discriminant validity.

Functionality (RII = 0.865) and Project Performance Impact (RII = 0.859) received the highest RII values, led by individual items on BIM software integration (Mean = 4.38) and schedule delay reduction (Mean = 4.38). However, the repeated-measures ANOVA showed no statistically significant differences between the criteria ($p = 0.348$), so this ranking is indicative only. The result suggests that G7 contractors perceive CBCMS implementation as an integrated socio-technical ecosystem requiring concurrent excellence in technological capability, human-centered usability, institutional support, and data governance.

Multiple linear regression analysis ($R^2 = 0.884$, $p < 0.001$) showed that Functionality ($\beta = 0.422$), Usability ($\beta = 0.323$), Data Management and Security ($\beta = 0.189$), and Organisational Support ($\beta = 0.186$) were significantly and positively associated with perceived project performance, although multicollinearity among the criteria means that these coefficients should be interpreted with caution. These findings provide actionable strategic guidance for contracting firms, suggesting that investments in digital platforms are more likely to be associated with project performance benefits when supported by interoperable BIM workflows, intuitive mobile field access, rigorous cloud data governance, and sustained employee upskilling.

Limitations and future research directions

Several methodological boundaries should be acknowledged. First, the sample was purposively derived from CIDB G7 main contractors (96.2%), which limits statistical generalization across small-and-medium enterprises (G1–G6) or client-side infrastructure authorities. Future research should implement cross-stakeholder comparative studies examining perceptual divergences among clients, consultants, and tiered subcontractors. Second, the study was cross-sectional and relied on self-reported perceptions; Harman's single-factor test showed that one factor explained 63.0% of the variance, so common method variance may have inflated the correlations among constructs, and the regression results indicate associations rather than causal effects (Podsakoff et al., 2003). Third, discriminant validity between the six criteria was limited, and the ratio of 130 respondents to 30 items is modest; future studies should refine the instrument with more distinctive items and test it with a larger, more diverse sample. Future longitudinal studies could also link the success factors to objective project records and utilise Structural Equation Modeling (PLS-SEM or CB-SEM), as applied in other construction management studies (Kamal et al., 2021), to capture complex mediating and moderating relationships across technology readiness, platform usage depth, and long-term financial performance.

ACKNOWLEDGEMENTS

The authors would like to express their grateful appreciation to Universiti Tun Hussein Onn Malaysia (UTHM) for funding this research under Tier 1 (Q446). Communication of this research is made possible through monetary assistance by Universiti Tun Hussein Onn Malaysia and the UTHM Publisher's Office via Publication Fund E15216. The authors would like to acknowledge the support of the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Campus, Johor, Malaysia, for providing the facilities and financial support for this research.

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