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Technology-Enhanced Communication and Contract Management in Construction Projects

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ABSTRACT

The significance of communication and contract administration in construction projects has been emphasized regarding their impacts on project success. Various technologies have been adopted to meet the project expectations in line with the objectives. Existing literature, however, offers inadequate exploration of the most effective technological tools for resilient communication and contract management processes. This study aims to investigate the technologies and their constructive impacts on one or both of the processes. A systematic literature review was conducted to explore the recent technological tools/methods. Then, the most effective technological advancements were evaluated through construction professionals' opinions and various statistical analyses were performed. Findings demonstrate that mobile applications, software tools, and cloud computing could effectively boost the practices in both processes. Results further indicate that blockchain and smart contract can contribute to improved contract management, while tracking technologies, mobile computing, and internet of things are more instrumental in the improvement of communication management. Understanding the technology that enhances the effectiveness of the processes can provide insights regarding the most critical technology in accordance with the project objectives. It would also contribute to an optimized allocation of project resources by using the most effective tools, which can support improved project management practices.

KEYWORDS

Collaboration; communication; construction projects; contract administration; technology

Introduction

Increasing volume, complexity, and uncertainty of construction projects due to rapid globalization require project parties to consider effective contract administrative practices (Gunduz & Elsherbeny, 2020a; Sertyesilisik, 2010). Contract administration can be defined as a process of managing and fulfilling essential project functions assigned to both parties from the initial stage (i.e., the contract is signed) to the final stage (i.e., the contract is terminated, or the final payment is completed) of the projects. The term "contract administration" can also be considered synonymous with the term "contract management" (Gunduz & Elsherbeny, 2020a). Improper contract administration was stated as one of the top three dispute causes by Arcadis (2021) industry report and has become an inevitable challenge for the construction industry. Along with its impacts on the occurrence and

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severity of disputes, poor contract administration entails several undesirable and unceasing consequences such as cost overrun, project delays, rework, and eventually may lead to project failure (Abdul-Malak & Khalife, 2017; Gunduz & Elsherbeny, 2020a; Msawil et al., 2022; Ye et al., 2015). Arcadis (2021) underpins that the disputes' average value is $54.26 million worldwide, and the average time of dispute settlement is around 13 months. Therefore, improving contract management practices can be regarded as a preventative approach to a variety of adverse consequences in construction projects.

Effective contract administration is created by maintaining high-quality relationships, the timely sharing of information, and building mutual trust between parties (Zhang & Xi, 2023). Proper communication between project stakeholders at the outset of contract management is a suitable setting to develop strategies to avoid many adverse consequences including the occurrence of disputes (Sabri & Torp, 2022). Such an enhanced communication can facilitate trust-building among project parties by enabling each member to better understand one another's requirements, motivations, and interests (Jiang et al., 2016), which also helps the team bounce back from adverse conditions. Owners and contractors have critical roles to prosper and monitor the communication processes in construction projects regardless of the existence of any disputes. Therefore, the ultimate aim of trust-based relationship between contracting parties should be developing incentive systems, ensuring good communication, and building of an effective team-working environment (Zaghloul & Hartman, 2003) to minimize the amplified damages caused by incompatible interests.

Given the interwoven relationships in project-based industries (Forcada et al., 2017), the inclusion of technological means to improve communication throughout contractual processes may offer a trustable environment for the stakeholders in the context of collaboration. This underlines a need to understand the synergistic relationship between communication and contract management with the help of technological means. Information and communication technologies (ICTs) are auxiliary to contracting processes addressing legal and relational issues (Nielsen et al., 2007) by reducing the complexity and intricacy of information sharing procedures (Arnold & Javernick-Will, 2013). Some technological tools (e.g., blockchain, smart contract) not only solve distrust-based issues commonly encountered in multi-party interactions in the absence of a behavioral enforcement, which is typical in legal and written contracts (Shen et al., 2023), but also mitigate conflicts between project parties (van Groesen & Pauwels, 2022). On the other hand, building information modeling (BIM), for instance, appears to have a significant role in the design-execution process intersection (Luth et al., 2014) and has widely been utilized to establish information sharing platforms, improve coordination and communication, and propose a significant advance in dispute resolution procedures (Enshassi et al., 2018; Greenwald, 2013). Therefore, digital and communication technologies can be integrated into contracting practices to enable collaborative and effective contract management (Gupta & Jha, 2023).

Several implementations of technological solutions in construction projects are crucial to project performance and make investment decisions regarding transition to innovative solutions. However, contract and communication management are essential competencies for the successful management of construction projects (Gunduz & Elsherbeny, 2020a; Khanyile et al., 2019). In this vein, as well as identifying the most commonly used technologies, understanding the extent to which these technologies can contribute to

communication/contract management is of great importance for the companies to make investment decisions. Furthermore, putting technologies and their efforts to the forefront in certain areas makes it possible to use them effectively and enhance the adaptation of construction firms to Industry 4.0.

In the light of above, this study focuses on improving communication and contract management processes in construction projects by addressing the constructive impacts of the technological tools on both or one of the processes. Accordingly, the research issues aimed to be addressed are fourfold: (1) to identify the most proper technologies for both of the management processes, (2) to investigate the underlying reasons why these technologies are used, (3) to evaluate the effectiveness and superiority of each technology by using statistical analyses, and (4) to understand how communication technologies are linked to the contract management-related performance.

To achieve the study objectives, a systematic literature review was conducted as the first step to find out the recent technological tools and methods influencing contract administration and communication performance in construction projects. Then, participants from the Turkish construction industry were sought to investigate the most effective technological advancements that support improvements in these areas. In the next step, several statistical analysis steps were applied to analyze the collective opinions of the participants. Since construction projects are mostly expected to thrive on limited resources, identifying the most appropriate technological tools and optimization of the project resources in efficient ways can contribute to improved project management.

Literature review

Technological innovations in communication management

Communication in construction projects, which necessitates constant information flow (Subramaniam et al., 2022), is of particular importance to manage a variety of information exchange due to their unique, temporary, and short-term project-specific requirements (Butt et al., 2016). Inherent nature of the industry causes complexity and intricacy in communication processes. Senescu et al. (2013) addressed that communication within-project, between projects, and across the industry might differ from one another. Suleiman (2022), on the other hand, stated that construction projects suffer from poor communication among team members, stakeholders, and/or project settings. According to Abbas et al. (2019), ineffective communication can cause conflicts, delays, failures, and significant changes in construction projects. To cope with these challenges, innovative technologies have widely been used to ensure proper data exchange and communication management.

In the era of data, technological revolutions made communication systems more effective (Kwofie et al., 2020). One of the most commonly used technology addressed in the literature recently is BIM (Enshassi et al., 2018; Ganbat et al., 2020; Liu et al., 2017; Villena Manzanares et al., 2023). For instance, Enshassi et al. (2018) stated that BIM was preferable to traditional approaches to improve coordination and communication, thus reducing the number of change orders, improving safety management practices, and ensuring effective project management. Ganbat et al. (2020) investigated the links between BIM and risk factors encountered in international construction projects and highlighted that many barriers in international engineering practices can be overcome via visualization models

of BIM. Liu et al. (2017) identified eight concepts to understand the impacts of BIM on collaboration and examined the effects of BIM support by classifying them based on three categories, i.e., technology, people, and process. The study highlighted that the ways of information exchange, direct access of parties to BIM models, organizational structure of the project, business purposes, and diverging requirements of multiple disciplines are factors related to communication that influence process-focused issues. Villena Manzanares et al. (2023) performed a research to explore whether effective communication was a mediation in the relationship between BIM technology learning and collaborative culture. They found that enhancing effective communication policies were linked to the use of BIM, and BIM utilization fosters collaboration and trust.

Cloud technology has also received growing attention by several scholars (Du et al., 2018; Oke et al., 2023; Won et al., 2022). For instance, Oke et al. (2023) investigated different implementation components of cloud computing tools such as platform, communication, software, data storage, and identified Microsoft Office live and e-mail as robust examples of fundamental communication tools. Du et al. (2018) developed a BIM and cloud-based system, namely collaborative virtual reality (CoVR), to improve interpersonal interactions among project stakeholders. Some scholars also addressed other technologies such as augmented reality (AR) (Nassereddine et al., 2022), virtual reality (VR) (Bao et al., 2022), web-based technologies (Anumba & Duke, 1997; Tam, 1999), radio frequency identification (RFID) (El Ghazali et al., 2012), and Internet of Things (IoT) (Dave et al., 2016) to improve communication in construction projects. In many of these studies, the primary concern of the authors was to improve data collection and sharing platforms (Bao et al., 2022; El Ghazali et al., 2012; Tam, 1999). For instance, Bao et al. (2022) adopted VR in safety training, and found that with proper technologies, real-time communication can be enhanced in construction projects. While Tam (1999) highlighted that internet can reinforce effective communication, El Ghazali et al. (2012) stated that one of the potential opportunities of RFID is to improve knowledge sharing. Therefore, it is essential to explore the integration of several technological means into project communication, as it would contribute a lot to the project management.

Technological innovations in contract management

The demand for large multinational construction projects is steadily increasing and accompanied by complex contract management systems (Sertyesilisik, 2010). As a result of complicated, voluminous and not easily readable construction contracts (Gurgun & Koc, 2022), it has become even more difficult to access essential information from the contract when needed and in the required format (Koc & Gurgun, 2022b). Mohamad Ibrahim and Zulkifli (2006) stated that errors, omissions, inadequacies, and unclarities of contract documents can cause frequent disputes and conflicts owing to erroneous interpretation of contractual statements. These facts could create a need for revolutionary changes in the contract management process with the advent in technology (Saygili et al., 2022).

In the context of contractual innovations, the adoption of new technologies and advanced methods enables the improvement of contract management processes and procedures through complete insight of their perceived advantages (Wahab et al., 2022). From a contractual and legal point of view, BIM-based applications have received considerable attention in the construction management literature (Almarri et al., 2019;

Assaad et al., 2020). For example, Assaad et al. (2020) examined the BIM provisions in standard national construction contract documents (i.e., American Institute of Architects (AIA) and ConsensusDocs) and offered BIM-based recommendations, such as immediate notification of errors in BIM data and ensuring the roles of the parties responsible for BIM management. Almarri et al. (2019) determined 23 legal risk factors in BIM associated with contractual issues and performed stakeholder-based evaluation. The researchers found that ambiguities in BIM documents, intellectual property rights and liability, inconsistent and/or missing data, and misunderstandings among project stakeholders were highly related to each other.

The adoption of blockchain-based systems and smart contracts in construction projects are also investigated by some researchers. For instance, Msawil et al. (2022) reported that blockchain-based platforms could improve the performance of contract management in terms of communication, financial, quality, and dispute resolution performance. Gupta and Jha (2023) examined the role of blockchain technology to confront contractual challenges in construction projects and found that developing collaboration among team members with the help of decentralized nature of blockchain could be a proper solution to misalignment problems in construction contracts. In another study, Ameyaw et al. (2023) explored factors influencing the adoption of smart contracts in construction projects and pinpointed that attributes such as trialability, relative advantage, competitive advantage, and compatibility played a significant role in the implementation of smart contracts. On the other hand, various machine learning and artificial intelligence applications have been realized to predict contract complexity (Zhang et al., 2023), dispute occurrence (Ayhan et al., 2022), or contractual changes (Khalef & El-Adaway, 2021).

Synergistic relationship between communication and contract management

Contract management performance is noticeably dependent upon communication among team members in the projects (Calik et al., 2025; Gunduz & Elsherbeny, 2020c). Effective contract management can only be achieved with the existence of the indicators of high-quality communication such as enhanced coordination, trust, and collaboration, improved clarity, and established strong relationships among contracting parties (Msawil et al., 2022; Zhang et al., 2023). In this vein, ICT resources and technologies endow an entire communication process more resilient and sustainable as they present a robust and seamless communication network linking all project participants (Dixit et al., 2021). Poor communication between project members, in contrast, may cause several challenges in contract administration logic such as ineffective claim management process (Cinko et al., 2023), dispute occurrences (Francis et al., 2022), and complex and incomprehensible relationships among contracting parties (Cheung et al., 2009). According to Mohamed et al. (2019), lack of communication leads to mismanagement in construction contracts, ultimately resulting in low customer satisfaction. To alleviate these issues, technological means can offer solutions throughout contract management life cycle (Alreshidi et al., 2017). All these research findings establish the foundation of the fact that the synergistic relationship between communication and contract management can be investigated to infer how technological advancements improve their performances. Figure 1 shows the impacts of communication in contract management process.

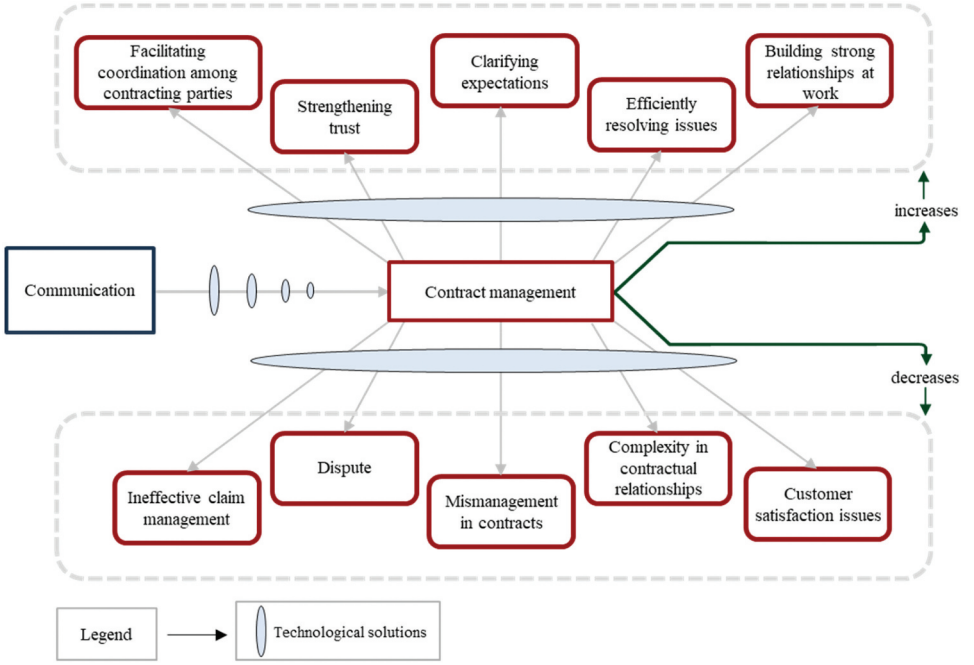


Figure 1. The potential impacts of communication attributes on contract management.

With reference to existing literature on specific technological tools, this study aims to reveal insights of innovative solutions that address both communication management and contract management within the broader context of a research network.

Methodology

The flow of the research is illustrated in Figure 2. In the first step, technologies suggested in the literature to address communication and contract management-related issues in the

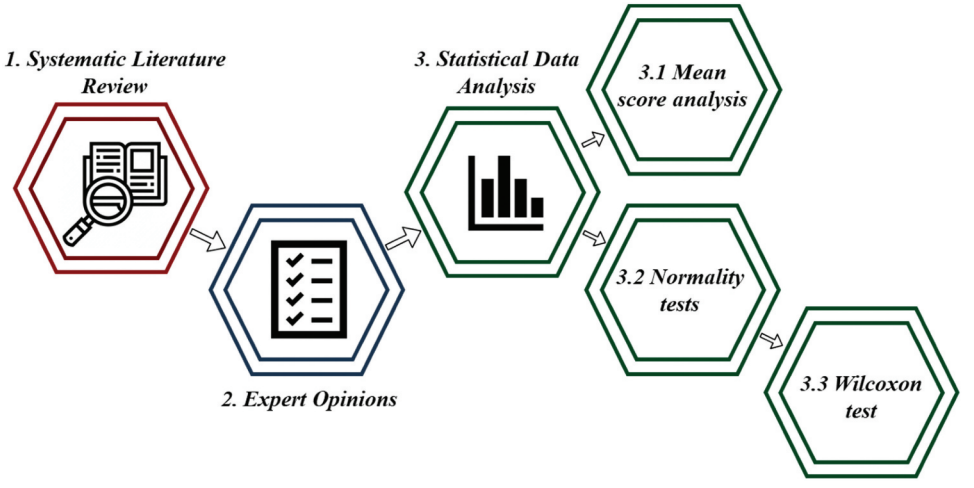


Figure 2. Research flow.

construction projects were probed by conducting a systematic literature review (Step 1). Then, opinions of construction professionals were collected to evaluate how these technologies would improve the performance of the processes (Step 2). Finally, the collective opinions were analyzed by using several statistical tests (Step 3) to investigate the impacts of the adopted technologies on one or both of the management areas. The details of the research steps are explained in the following sections.

Systematic literature review

In the initial step of the research, a systematic literature review on communication and contract management in construction projects was employed to establish the research background of technological means related to these areas. It was conducted by using Scopus search engine due to its comprehensive coverage, popularity, and effectiveness compared to other search engines (Hasan, Ghosh, et al., 2021; Koc & Gurgun, 2021). The search steps of the literature review to capture the past studies are illustrated in Figure 3. The selected keywords related to communication and contract management were "communication" and contract*, respectively; related to technology were technolog* OR "BIM" OR "building information modelling" OR "DLT" OR "blockchain" OR "smart contract" OR "GIS" OR "geographic information system" OR "GPS" OR "global positioning system" OR "sensor" OR "RFID" OR "radio-frequency identification" OR "ultra-wide band" OR "UWB" OR "barcode" OR "QR code" OR "software" OR "photogrammetry" OR "video" OR "camera" OR "multimedia" OR "laser" OR "LIDAR" OR "artificial intelligence" OR "machine learning" OR "cloud" OR "virtual reality" OR "augmented reality" OR "mixed reality" OR internet* OR "IoT" OR "big data" OR "ERP" OR "enterprise resource planning" OR "programming" OR "electronic" OR "e-supply" OR "e-procurement;" and related to construction were "construction industry" OR "construction project." Initially, 918 and

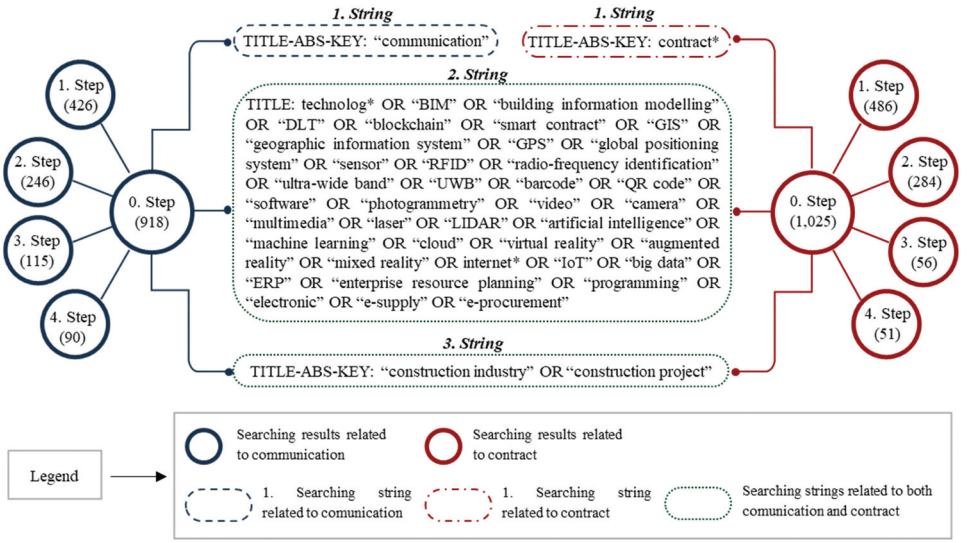


Figure 3. Flow of the literature review.

1,025 studies were retrieved regarding communication and contract management linked to technological tools, respectively (*Step 0*).

In the first step, search results were limited to journal articles written in English, which resulted in 426 articles for communication and 486 articles for contract management (*Step 1*). Only journal articles were included as they contain more extensive, valuable, and high-quality information than other types of documents such as conference papers, reports, and editorials (Hasan, Ghosh, et al., 2021). This step was followed by excluding the irrelevant articles based on topics such as energy, earth and planetary sciences, medicine, and chemistry (search results on communication and contract management: 246 and 284 studies, respectively) (*Step 2*). After reading the abstracts of these articles, 115 and 56 studies linked to communication and contract management areas were found suitable to this study (*Step 3*), respectively. In this step, (1) articles that were not directly related to the communication or contract management; (2) articles that only focused on technological tools without considering communication or contracting process; and (3) articles that investigated only the impact of technologies on the communication or contracting process in a general context, or vice versa (i.e., the effect of communication on technological innovation (Ma et al., 2023)) were disregarded. Finally, after the full paper investigation, 90 studies for communication and 51 studies for contract management were selected (*Step 4*). The exclusion and inclusion criteria during full paper investigation were the same as it is in abstract-level investigation.

Data collection and statistical data analysis

This study aims to explore top-ranked technologies affecting the success of construction projects with a particular focus on the communication and contract management and to explore participants' perception differences on communication and contract management regarding the identified technologies. In this vein, a questionnaire survey was prepared to evaluate and rank the technologies and determine differences and possible similarities in the role of technologies on communication and contract management. The questionnaire was designed threefold to: (1) determine general attributes/background of the participants; (2) inform participants about technologies or methods identified through the literature review (no input was required in this part); and (3) evaluate the technologies/methods for communication and contract management using 1 (least important) – 7 (extremely important) Likert scale. The details of the questionnaire are provided in Table 1.

Data collection was carried out between September and December 2023 in Türkiye. The questionnaire was distributed to potential participants in two ways: face-to-face and via e-mail. 474 participants, who were either interviewed in person or reached out online, from the construction industry provided responses. One of the participant selection criteria was to have at least 3 years of experience in the construction industry. Besides, participants in different roles (such as owner, contractor, designer, and sub-contractor) and with different professional backgrounds were sought to ensure a well-rounded perspective. In addition, all the participants were required to be familiar with the adaptation of technologies in the industry. The demographic details of the respondents are presented in Table 2. The "others" category in this table included technicians, accountants and economists, and urban and regional planners working in the construction industry. 38.8% of the participants have at least 3 years of work experience, indicating that they are sufficiently qualified to answer the

Table 1. Questionnaire: sections and questions.

Sections	Questions		
Respondent's profile	How many years of work experience do you have in the construction industry?		
	What is your profession?		
	What is your role during the project?		
A brief description of each technology			
Evaluation of technologies for communication and contract management	Please, evaluate the contribution of the technologies presented below to the project communication/contract management on seven-point Likert scale (1: least important – 7: extremely important).		
	Technologies	Communication	Contract management
	BIM	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Blockchain, smart contracts	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	GPS, GIS, smart sensor	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	RFID, UWB, Barcode, QR codes	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Mobile computing and applications	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Photogrammetry, videogrammetry, multimedia, laser scanner, LIDAR	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Machine learning, artificial intelligence	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Cloud computing	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Augmented reality, virtual reality, mixed reality	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Internet of Things (IoT)	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Big data	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Software tools	1/2/3/4/5/6/7	1/2/3/4/5/6/7
	Electronic-based technologies	1/2/3/4/5/6/7	1/2/3/4/5/6/7

Table 2. Respondents' demographic details.

Category	Item	Frequency
Work experience in the construction industry	3–4 years	184 (38.8%)
	5–10 years	111 (23.4%)
	11–20 years	134 (28.3%)
	More than 20 years	45 (9.5%)
Proficiency	Engineer	324 (68.4%)
	Architect	78 (16.5%)
	Others	72 (15.2%)
Stakeholder role	Owner	230 (48.5%)
	Contractor	126 (26.6%)
	Consultant	54 (11.4%)
	Designer	35 (7.4%)
	Sub-contractor	23 (4.9%)
	Supplier	6 (1.3%)

questionnaire. In addition, construction professionals with at least 3 years of working experience exhibited a good understanding of the communication and contracting process, as well as technological advancements in both areas.

The collected responses from the participants were initially analyzed using mean score to assess the impact of the technologies utilized for communication and contract management, and the technologies/approaches were ranked based on the mean scores. The mean score was calculated using the following equation (Omopariola et al., 2024; Shanika et al., 2023):

$$\text{Mean score} = \sum (\text{sxf})/\text{N} \tag{1}$$

where s = the score assigned to each technology by participants (i.e., ranging from 1 to 7 in this study); f = frequency of the responses; and N = total number of respondents.

Then, Kolmogorov–Smirnov and Shapiro–Wilk tests were conducted to determine whether the data were normally distributed (Hwang et al., 2022; Koc et al., 2022). The results implied that the responses were not normally distributed. Therefore, Wilcoxon signed-rank test was preferred as a nonparametric test for further analysis (Gurgun et al., 2022) to identify the existence of significant differences in the impacts of technologies on communication and contract management. It is one of the most useful tests to compare the scores of two groups (Group 1: communication and Group 2: contract management in this study), coming from the same participants (Bypaneni & Tran, 2018). In this study, statistical package for social science (SPSS) 17.0 was used for all the statistical analyses.

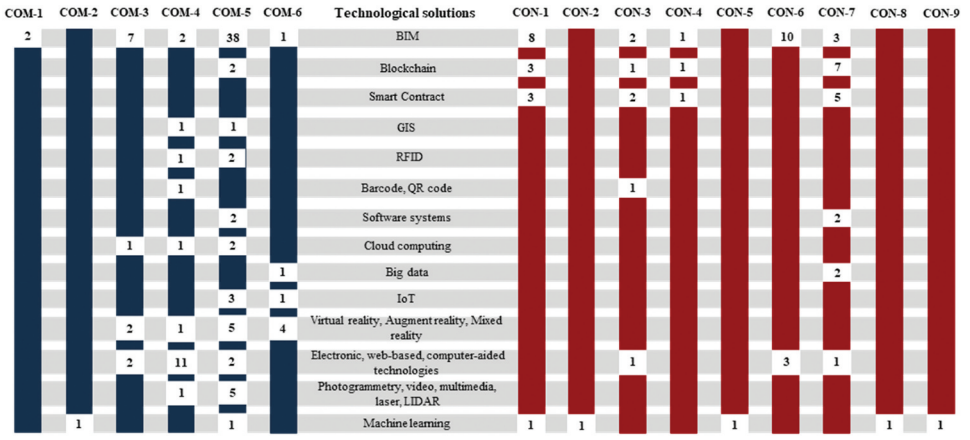
Results

Analysis of the adopted technologies

Technologies used for communication and contract management in construction projects were identified by conducting a systematic literature review. Figure 4 shows the most common reasons of using various technological solutions addressed in the reviewed studies. Focusing on the communication dimension, BIM stood out as the most adopted and researched technology for the projects (50 studies). The electronic-based, web-based, and computer-aided technologies (15 studies), and augmented, virtual, and mixed reality (12 studies) were addressed as the frequently used other means to enhance communication management in construction projects. Regarding contract management processes, BIM (24 studies), blockchain (12 studies), and smart contracts (11 studies) were identified as the prominent technologies preferred in the projects.

Ranking of the technologies based on data analysis results

Table 3 illustrates mean and standard deviation values obtained for each of the technological means. Participants identified the top four technologies on both communication and contract management practices as (1) mobile computing and applications (T5), (2) project management software tools (T12), (3) cloud computing (T8) and (4) BIM (T1) (Table 3). In addition, electronic-based technologies (T13) in communication context and big data (T11) in contractual context were rated as the fifth-highest technologies with 4.82 and 4.74 mean scores, respectively (Table 3).



Note: **COM-1:** Fostering communication; **COM-2:** Predicting communication level; **COM-3:** Facilitating communication management; **COM-4:** Establishing communication platform; **COM-5:** Ensuring effective communication; **COM-6:** Providing real-time communication; **CON-1:** Resolving contractual issues; **CON-2:** Analysing particular contract conditions; **CON-3:** Controlling/executing contractual rules; **CON-4:** Developing contracting framework; **CON-5:** Evaluating contractual risks; **CON-6:** Investigating contractual aspects/issues/risks of technology; **CON-7:** Managing construction contracts; **CON-8:** Measuring contract complexity; **CON-9:** Predicting contractual changes.

Figure 4. Most frequently used technologies and common reasons of their use. COM: Communication, CON: Contract management, and numbers indicate the number of studies.

Table 3. Descriptive statistics of responses.

		Communication			Contract management		
Code	Technologies	Mean score	Standard deviation	Rank	Mean score	Standard deviation	Rank
T1	Building Information Modelling (BIM)	4.84	1.63	4	4.76	1.61	4
T2	Distributed Ledger Technology (DLT)/blockchain, smart contracts	4.58	1.65	9	4.74	1.67	6
T3	Global Positioning System (GPS), Geographic Information System (GIS), smart sensor	4.51	1.65	12	4.44	1.67	11
T4	Radio Frequency Identification (RFID), Ultra-Wideband (UWB), Barcode, Quick Response (QR) codes	4.43	1.70	13	4.32	1.69	13
T5	Mobile computing and applications	5.12	1.62	1	4.90	1.58	1
T6	Photogrammetry, videogrammetry, multimedia, laser scanner, LIDAR	4.69	1.66	6	4.58	1.67	8
T7	Machine learning, artificial intelligence	4.58	1.70	8	4.51	1.66	9
T8	Cloud computing	4.85	1.70	3	4.79	1.61	3
T9	Augmented reality, virtual reality, mixed reality	4.52	1.71	11	4.46	1.70	10
T10	Internet of Things (IoT)	4.57	1.72	10	4.41	1.69	12
T11	Big data	4.65	1.61	7	4.74	1.66	5
T12	Software tools (such as ERP, EDI, XML, planning/scheduling software)	4.92	1.66	2	4.83	1.66	2
T13	Electronic-based technologies (such as e-procurement, e-commerce, and e-payment)	4.82	1.63	5	4.73	1.64	7

Results of Wilcoxon tests

Wilcoxon tests were applied to examine whether the effects of the technologies on communication and contract management differ from each other. The results are shown in Table 4. Findings indicate statistically nonsignificant differences in 9 of the

Table 4. Results of Wilcoxon test.

Corresponding technologies	Combination	*Z*	Asymptotic significance (2-tailed)
T1	T1-Communication/T1-Contract	−1,600[a]	.110
T2	T2-Communication/T2-Contract	−2,631[b]	.009
T3	T3-Communication/T3-Contract	−1,232[a]	.218
T4	T4-Communication/T4-Contract	−1,998[a]	.046
T5	T5-Communication/T5-Contract	−3,779[a]	.000
T6	T6-Communication/T6-Contract	−1,327[a]	.184
T7	T7-Communication/T7-Contract	−1,189[a]	.235
T8	T8-Communication/T8-Contract	−1,023[a]	.306
T9	T9-Communication/T9-Contract	−1,391[a]	.164
T10	T10-Communication/T10-Contract	−2,660[a]	.008
T11	T11-Communication/T11-Contract	−1,754[b]	.080
T12	T12-Communication/T12-Contract	−1,293[a]	.196
T13	T13-Communication/T13-Contract	−1,612[a]	.107

13 technologies (excluding T2, T4, T5, and T10) between communication and contract management at a 0.05 significance level. This means that both areas of project management were similarly affected by many of the emerging technologies in the construction industry.

Discussion

Technology-enhanced communication and contract management studies

As technological means have evolved rapidly (Saygili et al., 2022), they are efficiently used in communication and contract management practices in the construction industry. As indicated in Figure 4, having been widely recognized at the forefront of BIM capability in project communication reflects the role of BIM in improving communication (Smith et al., 2022) by providing direct information transmission networks (Huang et al., 2022). Electronic-based or web-based communication tools have been reported as practical tools to create functional communication platforms (Figure 4) such as voice-based intelligent virtual agent (VIVA) to achieve real-time data communication (Linares-Garcia et al., 2022), electronic procurement system (Aduwo et al., 2020; Deraman et al., 2019), and online platform for building terminological consensus in architecture, engineering, and construction (AEC) field (de Oliveira et al., 2024). Enabling a realistic approximation of emerging communication technologies significantly rely on augmented and virtual reality technologies, and better communication and collaboration are often challenging aspects of construction projects (Abbas et al., 2019, Nassereddine et al., 2022).

Findings show that BIM (24 studies), blockchain (12 studies), and smart contracts (11 studies) are the most significant technologies in contract management processes (Figure 4). For example, using BIM was addressed in various studies (Almarri et al., 2019; Assaad et al., 2020; S. L. Fan et al., 2019) as a mean to cope with the contractual and legal risks. It is presented as a useful tool in dispute resolution, claim settlement, and conflict management (Abd Jamil & Fathi, 2020; Araya, 2019; Muhammad & Nasir, 2022). As recently emerging information technological advancements, blockchain and smart contract-based applications were referred as practical digital tools to manage construction contracts automatically (Gupta & Jha, 2023). These progresses were also found useful for protracted dispute

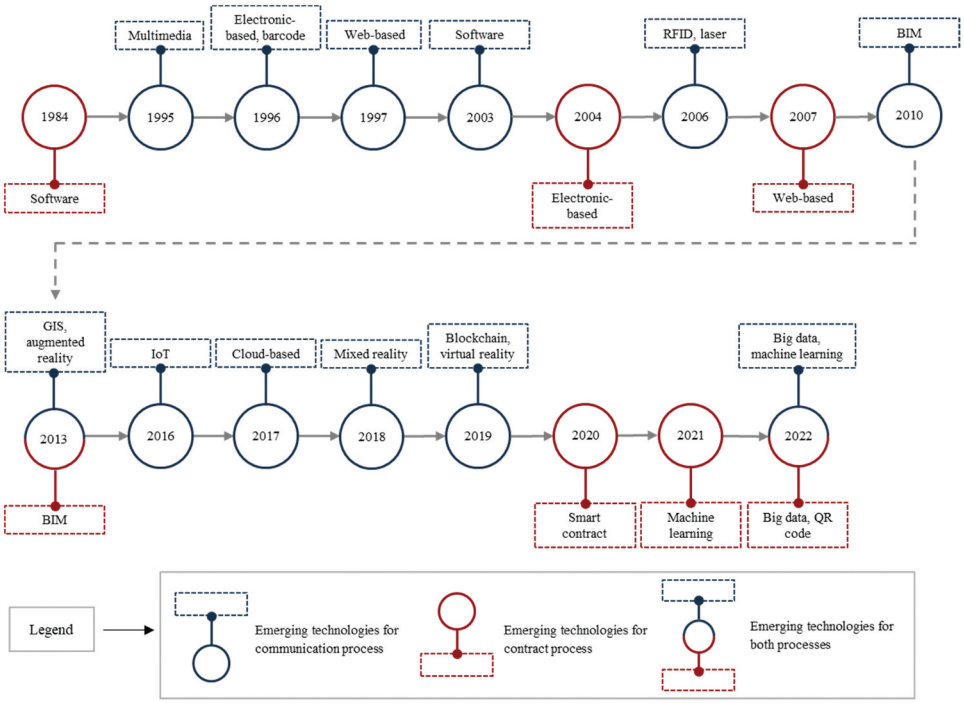


Figure 5. Chronologic adoption of the technological solutions for communication and contract management in the articles.

resolution processes sourcing from the multidisciplinary environment of the industry (Cheung et al., 2020).

Figure 5 shows the chronologic implementation order of the adopted technologies for communication and contract management purposes. The microcomputer software was first utilized in 1984 to execute managerial functions, in which contract management was one of the three major management areas (O'Connor & Kruppenbacher, 1984). In the context of communication management, tools, multimedia systems, electronic-based and web-based technologies had been reported frequently in the literature between 1995 and 1997. Thorpe et al. (1995) highlighted that video conferences and remote multimedia systems were critical tools for communication and informal information exchange among different departments. Finch et al. (1996) developed an electronic document system supporting barcode tool to convey drawing information from designers to site personnel. In dealing with the changing needs of project teams in construction projects, the internet and intranet played a key role in facilitating access to accurate project team member as well as ensuring secure communication within a project team (Anumba & Duke, 1997).

By 2003, use of ERPs came along and used for enterprise-level business administration, ensuring a communication platform between teams, projects, and subcompanies (Shi & Halpin, 2003). In the examined articles on contract administration, an electronic-based bidding procedure was presented by Wang (2004) to manage unbalanced bidding and provide fair contract environments for each contracting party. On the other hand, literature survey showed that automated reality capture

and data collection technologies such as RFID and laser scanners have been adopted for communication since 2006. For instance, Akinci et al. (2006) conducted a case study to rebuild the information flow process to address potential implications of these technologies. Meanwhile, a tool for configurating and negotiating construction contracts over the internet, namely eLEGAL, was developed. The implementation of the eLEGAL framework indicated that it not only strengthened trust and business relationships but also minimized administrative overhead (Nielsen et al., 2007).

BIM has been addressed since 2010 as a dominating technology to investigate whether closer collaboration and communication across different disciplines, projects, and/or companies were fostered (Dossick & Neff, 2010). It has also been referred as a tool for contract management since 2013 to minimize contractual complexities (Kuiper & Holzer, 2013). Concurrently, BIM was introduced together with augmented reality to enable better interaction and communication (X. Wang et al., 2013). By 2013, the number of integrated solutions increased such as GIS-based integrated information model proposed by Dib et al. (2013) in detecting miscommunication and preventing information loss. Dave et al. (2016) advocated that adopting IoT communication standards could enhance the efficiency of information flow throughout the project life cycle. In 2017, the importance of cloud infrastructure enriched by BIM platform was emphasized by Alreshidi et al. (2017) in managing the construction of data flow and thus aiding collaboration process within project teams. In 2018, mixed reality, as a design communication method, was used to transfer three-dimensional (3D) BIM content to construction workers on site (Chalhoub & Ayer, 2018).

Another recently considered technology in construction projects is virtual reality, which enables visualization, detects design errors, improves communication, and develops efficient simulations (Davila Delgado et al., 2020). In the reviewed articles, virtual reality-based communication systems were generally used to address real-time problems by connecting remotely located project stakeholders (Abbas et al., 2019). Meanwhile, blockchain implementations were suggested to be a solution that could ensure easier collaboration as it provides access to current and constantly updated information (Safa et al., 2019), and these advancements contributed to the development of smart contract systems. For example, a secure progress payment system for construction contracts was proposed by Ahmadisheykhsarmast and Sonmez (2020). On the other hand, machine learning methods have been receiving more attention since 2021 focusing on communication and contract management. For instance, Khalef and El-Adaway (2021) used several machine learning methods (e.g., ANN, SVM, RF, KNN, XGBoost, and LR) for classifying and predicting the changes in the contract. Chen et al. (2022) pointed out that integration of communication technologies with artificial intelligence (or specifically machine learning) techniques can enhance managerial collaboration with digitally assisted tools. As shown by van Groesen and Pauwels (2022), Quick Response (QR) code, one of the tracking techniques, could be combined with blockchain and smart contract technology to track compliance to the contract terms.

Collective data analysis of the technological means

Technological approaches have become critical instruments to gain deeper insights for legal arguments and contractual practices (Guévremont & Hammad, 2020; Liao et al., 2019) as

well as for more efficient business communication processes (Won et al., 2022). Thus, over the last decades, a variety of studies have investigated technological means to improve communication and contract management in the projects, as described above. Professionals from the construction industry addressed that mobile computing and applications (T5), and project management software tools (T12) were the most effective technologies for both communication and contract management practices (Table 3). These findings are in parallel with the study of Hasan et al. (2018), who found that ensuring timely access to data and effective contract management via mobile ICT applications were of utmost importance in construction projects. Mobile applications could be integrated with other technologies, such as BIM, augmented reality, RFID, QR codes, barcodes, and wireless connection to facilitate real time multi-directional communication and data acquisition (Alsafouri & Ayer, 2018). Employees and site personnel could be reached even outside of the working hours by the use of mobile technologies (Mokhtar Azizi et al., 2023) and efficient management of the projects could be achieved remotely as a result of such a practical information exchange (Hasan et al., 2018). From the contracting point of view, mobile applications can contribute to both monitoring and measuring contract management performance throughout project life cycle (Gunduz & Elsherbeny, 2020b). In addition, automated contract administration enables real-time payment transfers using mobile applications (Kamel et al., 2023). ERP systems are also regarded as one of the most effective tools for expediting secure data transfer among project teams, effective access and allocation, and improving project management efficiency (Gavali & Halder, 2020; Sarkar et al., 2022). With the integration of planning software into contract management, changes can be efficiently accommodated and disagreements between project stakeholders can be prevented with regard to their rights and responsibilities (Abdel-Khalek et al., 2019).

Cloud computing (T8) and BIM (T1) were also frequently used tools for communication (with mean scores of 4.85 and 4.84, respectively) and contract management (with mean scores of 4.79 and 4.76, respectively) (Table 3). As opposed to the findings of Noruwa et al. (2020), this study found that mobile applications and cloud computing are more preferred than BIM. Considering the ICT applications in construction sector, this result corroborates the earlier findings of Gajendran and Perera (2017), who found that internet and computer aided design (CAD) were more prevalent than cloud computing and BIM for construction firms in Australia. Still, cloud computing technologies are more preferred in the construction industry compared to other sectors (Won et al., 2022), as it plays an important role in achieving coordination, collaboration, communication and reducing communication errors between on-site and off-site employees (Oke et al., 2023; Waqar et al., 2023; Won et al., 2022). In legal context, it can also be used as a cost-effective solution for storing and securing data across multiple disciplines (Olatunji, 2016).

BIM (with 3D model, time, and cost parameters) is a convenient platform to the digitalization in construction project management and improve multi-party communication among project teams since it facilitates receiving necessary approvals and enables different departments to work and collaborate in the same environment (Al-Ashmori et al., 2020; Gaur & Tawalare, 2022). In fact, the ability of BIM to convey information smoothly and systematically as well as to create a communication channel was also addressed by many researchers over the last decade (Aka et al., 2021; Lin et al., 2019; Oraee et al., 2022; Smith et al., 2022), probably more so than other methods and tools. Still, BIM adoption in construction projects firmly depends on well-structured, explicit, and clear

contractual provisions and guidelines (Muhammad & Nasir, 2022), which contributes to minimization of disputes and disagreements (Nilchian et al., 2022).

According to the findings, electronic-based technologies (T13) in communication context and big data (T11) in contractual context were observed with 4.82 and 4.74 mean scores, respectively (Table 3). The benefits of implementing the electronic-based technologies, i.e., information sharing with the desired quality, acquiring real-time feedback from other workers/teams/projects, actively communicating with others, and meeting customers' demands would make a significant contribution to enhance the overall communication performance of organizations (Gurgun et al., 2024; Yevu et al., 2022). However, existing literature on construction management that uses e-procurement solutions usually focuses on its role in tendering and contract management rather than a tool for communication (Laryea & Ibem, 2014). It is important to note that the contract data is difficult to collect due to the characteristics of construction contracts (Lee et al., 2019). As opposed to the potential of big data in advanced information flow management (Li et al., 2020), this study offered the functionality of big data analytics on contractual aspects. Therefore, big data applications can be useful for successful contract management, and supportive for the project team to access, store, and analyze data in a reasonable and desired depth (Atuahene et al., 2022). Overall, the impacts of electronic-based technologies on both communication and contract management were evaluated close to each other, which makes the adoption of such technologies not only advantageous in terms of overall project management performance, but also practical for the stakeholders as well.

Here, it should also be noted that cost implications of technologies are also critical for their implementation. One of the main reasons for increased adoption of mobile computing/applications is that most of the mobile applications used by construction companies are free or can be accessed easily with low-price (Barbarosoglu et al., 2016). The implementations of other top ranked technologies (such as software tools, cloud computing, BIM, and e-procurement systems) may require high initial investment costs due to the need for acquiring the software, maintaining and upgrading technological infrastructures, providing services over the internet, and staff training programs to use them (Gurgun et al., 2024; Hall et al., 2022; Kim et al., 2016; Won et al., 2022). In addition, big data is regarded to be more costly due to the high infrastructure, data storage and processing, and hardware equipment costs (Sivarajah et al., 2017). Therefore, costs to use technologies such as implementation, acquisition, training, integration, and licensing can be regarded as barriers to their widespread adoption.

Communication/Contract relationship

Wilcoxon test was applied and it was implied that the impacts of T2, T4, T5, and T10 were statistically different in the context of communication and contract management (Table 4). This can be explained by the fact that once a method or tool has gained functional diversity within the processes, that method can also be useful for meeting the expectations in various areas (i.e., communication and contract management) in construction projects (Abd Jamil & Fathi, 2020; Du et al., 2018). It can be noted that these technologies or applications are promising for effective decision-making in many aspects of project management (Alsafouri & Ayer, 2018).

Blockchain and smart contracts (T2) were evaluated to be more instrumental for contract management (mean value of 4.74) than for communication management (mean value of 4.58) (Table 3). While blockchain mainly focalizes on improving transparency and building trust in contracting processes (D. Lee et al., 2021), smart contracts concentrate on recording, storing and updating contract data accurately to save time and minimize conflicts (Wahab et al., 2022). Smart contract-based blockchain technology was addressed by Wahab et al. (2022), who found that this technology could save time up to 90% with nearly 100% accurate and reliable information. Here, even though blockchain and smart contracts were evaluated with lower impacts on communication context (compared to the contractual aspect) (Tables 3 and 4), they can also offer a platform to better communicate and foster relationships among project parties to streamline work activities (Kunkcu et al., 2023; Yang et al., 2020). Realizing these potentials opens up all of these applications to obtain beneficial outcomes for diverse industries such as finance, government, construction, healthcare, and supply chain management (Sharabati & Jreisat, 2024). Despite the benefits of blockchain/smart contract applications, their adoption in the industry is limited due to (1) the reluctance of stakeholders regarding data sharing (Wu et al., 2022), (2) interoperability issues across multiple blockchain platforms (Wu et al., 2022), and (3) their relatively high initial and maintenance costs (Sharabati & Jreisat, 2024). Nevertheless, the use of blockchain/smart contracts in the construction sector offers practical advantages such as data security, improvement in payment processes, data management, and removing transaction costs (Li et al., 2019), which may allow the contracts not to be changed and provide a reliable working environment.

Looking into the mean values of RFID, ultra-wideband (UWB), barcode, QR codes (T4), mobile computing and applications (T5), and IoT (T10), they were considered with mean values of 4.43, 5.12 and 4.57, respectively with considerable advantages in terms of communication compared to contract management (Table 3). All these technologies (T4, T5, and T10) aim to collect real-time data, and communication is proliferated by the provision of data and information. RFID may be useful for smooth performance of communication processes by encouraging teamwork, cross-fertilization between tasks, and information transmission (Mabad et al., 2021). Technologies such as barcode and QR code that automatically capture the required data can prevent data entry errors (van Groesen & Pauwels, 2022), which advocates accurate data flow supporting communication among construction parties. In addition, as massive and intricated information is produced in construction projects, this information should be managed efficiently, and data sharing platforms using mobile apps is a straightforward solution to this (Barbarosoglu et al., 2016), explaining why it was found more useful for communication management than contract management. Therefore, mobile applications can be considered essential in effective information sharing, increasing decision-making quality, and enhancing collaboration (Hasan, Rameezdeen, et al., 2021). According to the study of Arowoiya et al. (2020), RFID and barcode were the most widely used technologies in IoT-based frameworks in the construction industry, highlighting their synergistic role in enhancing communication management. Considering the IoT features such as remote control and monitoring (Huang et al., 2022), the availability of vital information throughout the life cycle of construction projects can be ensured through the IoT applications (Wang et al., 2022).

Interpretation of results

This study shows which of the implemented technologies or tools should be given priority to meet a wide range of needs in construction projects. Different from existing studies based on the literature review research for technology and construction context (Chen et al., 2022; Noruwa et al., 2020), this study focuses on their use and functionality in communication and contracting context. A summary of the technologies that play critical roles in communication and contract management is presented in Figure 6. The tools that facilitate improved communication (i.e., IoT, multimedia/photogrammetry, electronic-based technologies, and machine learning) can expedite the completion of projects by connecting teams and synchronizing tacit information (Arowoiya et al., 2020; Shoar et al., 2022). Such advanced tools enable project parties to have active and productive roles by effective remote

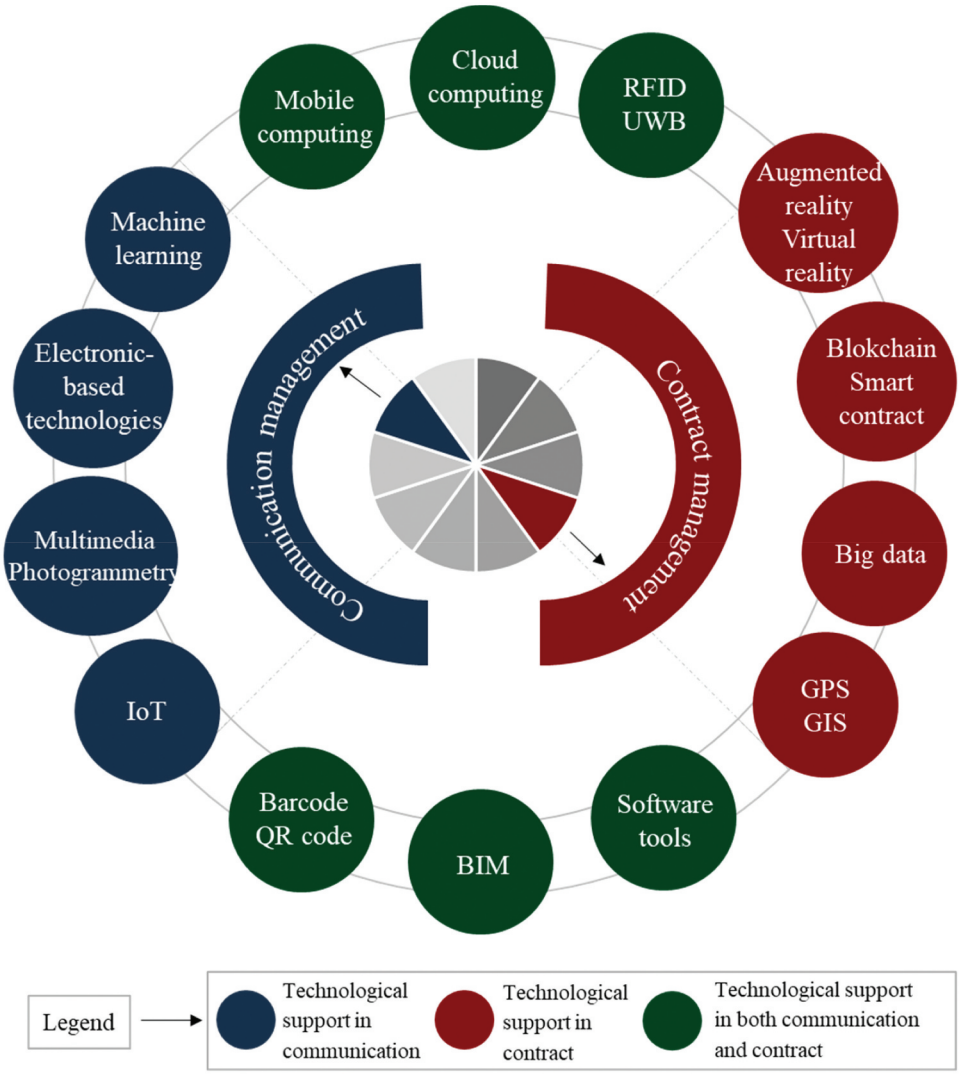


Figure 6. Summary of the critical technological support for communication and contract management.

working without relying on the boundaries of a particular person or location (Mokhtar Azizi et al., 2023). Data acquisition techniques (i.e., multimedia, photogrammetry, videogrammetry, multimedia, laser scanner, and LIDAR) are prominent tools once there is a need to transmit daily, weekly, or monthly collected data more smoothly (Alsafouri & Ayer, 2018; Loosemore, 2011). Isikdag (2019) reported that electronic-based platforms can promote better communication and coordination to respond to requirements of the projects, particularly in supply chain practices. On the other hand, technologies that provide guidance on contract management (i.e., AR/VR, blockchain/smart contracts, big data, and GPS/GIS) can help saving time, reducing human errors, and ensuring greater consistency in contracts (Ibrahim et al., 2022). Given that these technological tools allow the implementation of routine and repetitive procedures in the contracting process, construction practitioners can devote their time to resolving more complex issues, thus enhancing the project performance (Saygili et al., 2022). Tracking systems, big data solutions, and augmented/virtuality reality technologies are suggested useful for projects at various contract types and delivery systems (Ibrahim et al., 2022; McNamara & Sepasgozar, 2021). Since changes are inevitable in construction projects (Koc & Gurgun, 2022a), BIM can be useful in recording and reviewing changes in real time (Abd Jamil & Fathi, 2018), and providing communication and collaboration among different departments/team members (Alreshidi et al., 2017). Legal processes and contract provisions can be supported with digital tools such as barcode, QR code, and RFID (Fan, 2020). All these advantages can be considered to improve project management practices in general, and communication and contract management in particular, which would contribute to effective project resource allocation.

Implications

Construction projects consist of unique contract arrangements and temporary stakeholder collaborations, making it unlikely for interactive and long-term relationships to be developed among contracting parties. Innovative practices support a dynamic collaboration process and a participating work environment in organizations. Establishing proper communication mechanisms among contracting parties plays a critical role in conflict resolution. Emerging technologies might be favorable to reduce misunderstandings and misinterpretations of contract clauses, thereby promoting contract performance efficacy. Training of project teams can be planned to perform successful integration of technology into the processes. Overall, the sustainability of long-term communication not only assists project team members to maintain their workflow without interruption but also fosters their willingness to share information, building a foundation for data-centric bridges that propel evolution into new territories. Technological development is an important part of Industry 4.0, which is recently evolving into Industry 5.0. Application of smart systems and establishing connectivity among the processes would pledge certain gains in project management.

Conclusions

Technological solutions are prevalent means for communication and contract management processes in construction projects. This study aims to review the technological approaches that can be adopted in the context of communication and contract management and clarify

their roles in project management. It is assumed that identifying the tools that serve for both of the management areas or selecting the most useful means for one of them in line with the project objectives would be practical in the decision-making processes and hence, pave way to successful project management implementations. Using financial and other resources based on the capabilities of the technological tools would be practical in the achievement of primary objectives of the projects.

Acquiring opinions of professionals from the construction industry and deriving collective evaluations was an important step in this study, since their experience and perceptions were critical in investigating the intended aims of the study. The mean rank analysis showed that the use of mobile computing and applications, software tools, and cloud computing would enhance the practices related to both communication and contract management. These trends in technological development could enable construction projects with limited resources to achieve a common impact on the communication and contracting processes while promoting the adoption of potentially less costly technologies. It was observed that existing literature promotes virtual reality and blockchain/smart contract-based solutions frequently as they are recently emerging. Such means may require more initial financial resources than less sophisticated fundamental tools such as mobile applications, software tools, cloud computing, which were evaluated at higher ranks. This can imply that professionals working in the field are interested in more fundamental-level instruments when the technological tools are concerned. This may not only be due to higher initial costs but also understanding the basic needs of fundamental technologies and their respective advantages in the projects. Since technological evolution is inevitable, the gap between theory and practice demands being addressed by the researchers. Statistical analysis results indicate that many of the investigated technologies had positive impacts on communication and contract management at the same time. Still, industry participants also highlighted the advantages of some of them in each area separately. These findings are expected to provide practitioners with a clearer approach to integrate the most feasible technological investments in the processes and better use of limited resources. Some specific recommendations to stakeholders involved in construction projects can be summarized as follows:

- Owners can use blockchain technology to have more secure and transparent communication, to trace processes in real-time, and to develop an effective web-based system for contract and communication management. In addition, with the integration of web-based systems, owners can streamline contract management procedures, enhance the effectiveness of decision-making processes, and adopt more cost-effective solutions against claims, disputes, and miscommunication.
- Contractors and/or sub-contractors can adopt BIM technology, which offers a collaborative environment and smooth access to real-time data, to minimize conflicts, claims, and misunderstandings. With the help of visualization capabilities for the information, BIM can reduce the number of requests for information, leading to enhanced proactive conflict resolution, and improved approach for meeting cost, time, and quality objectives of the projects.
- Consultants can utilize virtual tools such as virtual reality, BIM, and artificial intelligence (AI)-driven solutions for the early detection of design errors and discrepancies in project documents. By incorporating these technologies into their practices, consultants can monitor the projects more frequently, control them more systematically,

sense issues within projects earlier, and ensure the successful delivery of projects. Hence, consultants can also adopt a proactive project management approach, instead of a reactive approach.

- Designers can use visualization tools such as two-dimensional (2D) or 3D images, diagrams, charts, and BIM models to communicate with site personnel easily. These tools can increase the accuracy and clarity of communication (i.e., document-based or informal communication), which can ultimately reduce reworks and ineffective workflows, minimize misunderstanding of the design intentions, and support collaborative environment.
- Suppliers can utilize web-based/online procurement platforms to create clearer communication channels with the contractors, sub-contractors, and owners of the projects. In this way, a data-driven supply chain management framework can be sustained in construction projects, which improves contract compliance, prediction of material demands, and optimization of logistics operations.

This study offers unique contributions to the pertinent literature by combining communication process with contract management via technological solutions since the implementation of technologies in communication can boost contract management performance, and vice versa. While existing literature on communication and contract management technologies primarily addresses their overall impact, this study provides a comprehensive analysis that can guide construction communication and construction contract disciplines in adopting more effective technologies. Furthermore, the current study contributes to the literature by summarizing which technologies should be used under which conditions and why in both management areas, supporting resource management efficiency. Besides, by tracking the evolvement of the technologies over the last decades that presents a visible change in the existing workflows of both communication and contract management areas, this study contributes to construction management knowledge in the industry 4.0 era.

This study contains some limitations that future studies can address. The collected data reflects the evaluations of professionals working in the construction industry in Türkiye. Although some of the participants may be experienced in the international businesses, this fact may still present local assessments. Generalization of the outcomes can therefore be obtained by investigations originated in other countries to include economic, cultural and social variations, which would extend the generalization of the findings and compare the perception differences of diverging economic and industrial conditions. Hence, researchers can use questionnaire survey established by the current study for effective communication and contract management in different regional contexts. Future studies may also include higher number of respondents to strengthen generalization of the outcomes. This study investigated the impacts of the technologies on contract and communication management. Addition of other performance criteria such as time, cost, quality, safety, and sustainability would present a wider insight to the relationship between technological innovations and project performance. Methodologically, the potential relationships or clustering among the technological solutions based on their effectiveness were not analyzed in this study. Such underlying relationships among the technologies can be explored using other methods such as factor analysis or principal component analysis, which can contribute to the communication and contract management literature. Overall, this research, with the above-

mentioned improvements, can address particular solutions to project performance criteria that are challenged by ineffectiveness throughout project management – a vital component in the era of data.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

All data supporting the findings of this study are available from the corresponding author upon reasonable request.

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