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APPRAISAL OF MOBILE APPS FOR COMMUNICATION AND COLLABORATION AMONG CONSTRUCTION PROJECT TEAMS

Yankah, J. E.[1], Adjei, K. O.[2], Bonney, S. O.[3], Kotey, S.[4], and Tieru, C. K.[5]
[1,4 &5]Department of Construction Technology and Management, Cape Coast Technical University, Ghana.
[2]Department of Building Technology, Faculty of Built and Natural Environment, Kumasi Technical University, Ghana.
[3]Department of Built Environment, School of Built Environment, University of Environment and Sustainable Development, Ghana.
[2]kofi.oadjei@kstu.edu.gh

ABSTRACT

Purpose: The construction industry faces communication and collaboration challenges, leading to delays, errors, and increased costs. This study investigates the impact and effectiveness of mobile apps in enhancing internal and external communication and collaboration in the construction industry.

Design/Methodology/Approach: The research design consisted of five phases: familiarisation with the study topic, literature search for construction apps, selection of apps, assessment and categorisation of apps, and validation of app functionality. The selection of apps was based on their versatility, capability to perform multiple tasks, market popularity, relevance to communication and collaboration, readability, and range of functions. Empirical study articles were used to validate and assess the functionalities claimed by the app developers.

Findings: Out of the 65 mobile apps evaluated, only 12 met the exclusion criteria for assessing the practicality of their functions through empirical evidence. Mobile apps like Slack, Microsoft Teams, SmartBidNet, and Basecamp have the potential to significantly enhance communication, collaboration, and decision-making processes in the construction industry.

The Research Limitation: The study identified and evaluated only 12 mobile apps out of 65, based on the exclusion criteria established to evaluate the practicality of the applications' functions through empirical evidence. This limited sample size may not fully represent the range of mobile apps available for communication and collaboration in the construction industry.

Practical Implication: The mobile apps to be used by project team members have the potential to replace traditional methods, particularly for geographically dispersed teams, leading to improved project efficiency and accuracy.

Social Implication: Mobile apps facilitate real-time communication with local communities, allowing construction projects to address concerns and involve community members in the decision-making process.

Originality/value: The study contributes to the existing body of knowledge by providing insights into the availability, accessibility, and competencies of mobile apps in improving internal and external communication and collaboration within the construction industry.

Keywords: *Collaboration. communication. construction industry. mobile apps. project management*
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INTRODUCTION

Construction project site administration and management involve numerous internal and external communications and collaborations, which are essential for successful construction project management and delivery. However, the construction industry still faces challenges in these areas, such as delays, errors, and increased costs (LetsBuild, 2022). The magnitude of these challenges and their persistence in construction management highlights the necessity of alternative approaches to handle communication and collaboration challenges.

Mobile apps are noted for their unique capabilities that can be harnessed to address the enormous communication challenges among construction team members. As a result, mobile apps can play a crucial role in addressing the communication and collaboration challenges in the construction industry. The capabilities cover real-time communication, improved collaboration, and efficient data management (Patel, 2023). These are the critical factors that promote communication efficiency and can, therefore, lead to project success.

These apps provide construction professionals with many tools and functionalities to improve efficiency and productivity. They offer features such as design and drawing apps, measurement and estimation apps, management apps, and construction site apps, which help streamline construction operations and tasks (Yankah, Novieto, Davies, & Adjei, 2022). Mobile cloud computing (MCC) also enables construction workers to access applications remotely, providing mobility and ubiquitous data access, further enhancing communication and collaboration (Silverio, Renukappa, Suresh, & Donastorg, 2016).

Despite these benefits, the uptake of mobile apps in the construction industry is still relatively low because of factors such as the cost of software and licensing (Liu, Mathrani, & Mbachu, 2016). The adoption of this new technology in the construction industry has been slow owing to a lack of awareness and familiarity within the design and engineering community and limited supply (Agarwal, Chandrasekaran, & Sridhar, 2016). However, the benefits of mobile apps in the construction industry are widely recognised. However, there are limited studies on the barriers hindering mobile app adoption in the construction industry and developing strategies to overcome these challenges.

However, in recent times, construction managers have shown a positive attitude towards using mobile apps, with an interest in both the strategic and operational levels of app usage (Liu, Mathrani, & Mbachu, 2019). Again, developing mobile apps specifically tailored to the construction industry can help simplify work processes and improve communication and collaboration between construction workers (Kim, Ok, & Kim, 2017).

This study, therefore, seeks to appraise mobile apps that are relevant for communication and collaboration among construction managers. It seeks to identify the specific mobile apps useful for addressing communication challenges. It examines their capabilities and matches them against the

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specific functions. This will guide users in selecting appropriate apps for communication and collaboration issues in construction management.

THEORIES OF THE STUDY

Communication Theory

Communication theory explores how information is transmitted, received, and understood between individuals or groups. Effective communication is crucial for high productivity and successful project delivery in the construction industry context. However, there are challenges and barriers to effective communication in this industry, such as the disjointed nature of construction activities, advanced communication technology, and the involvement of workers from various disciplines and backgrounds (Özçetin, 2023). Various strategies have been identified to improve communication in the construction industry, including technological-based strategies, integrated process strategies, and human engagement strategies (Yermolaieva, 2020). Ejohwomu, Oshodi, & Lam, (2017) identify unclear project objectives, ineffective reporting systems, and poor leadership as significant barriers to effective communication in the Nigerian construction industry. These findings highlight the importance of clear communication channels, well-defined project goals, and strong leadership in facilitating effective communication (Ejohwomu, Oshodi, & Lam, 2017). Additionally, mobile apps can improve communication and collaboration by providing a platform for efficient information exchange and real-time communication among team members (Ohueri, Habil, & Liew, 2023). Barbarosoglu & Arditi (2016) discuss the current state of smartphone applications available to the construction industry, highlighting their functions in field data collection, project management, and other areas (Barbarosoglu & Arditi, 2016). By implementing these strategies and utilising mobile apps, the construction industry can overcome communication challenges and enhance productivity and profits (Barge, 2022). Communication Theory can help explain the challenges and barriers to effective communication in the construction industry. Mobile apps have the potential to address these challenges by improving communication and collaboration.

Collaboration Theory

Collaboration Theory is a theoretical framework that examines how individuals or groups work together to achieve common goals. It explores the factors hindering collaboration among construction project teams and identifies strategies or tools to facilitate effective collaboration. It can provide insights into the factors that hinder collaboration among construction project teams and how mobile apps can facilitate effective collaboration. Salam, Forsythe, & Killen, (2023) found that successful collaboration in construction projects requires understanding how participants view collaboration, such as facilitation factors, working processes, and outcomes. Ramanath & Rybkowski (2023) explored the correlation between educational background and collaboration tendencies among project stakeholders, while Deep, Gajendran, & Jefferies, (2019) highlighted the importance of collaboration in large capital-intensive construction projects. Ruge, Dimitrova, Grubbauer, & Bögle, (2022) introduced the concept of "artefacts of collaboration" to analyse how collaborations emerge and unfold across disciplines and project stages. Nath, Reja, & Varghese, (2021) developed inductive theories for psychological factors and project-level enablers of

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collaboration in construction projects. These studies provide valuable insights into understanding and improving collaboration in the construction industry.

Information Processing Theory

The Information Processing Theory is a theoretical framework that explores how individuals acquire, process, and utilise information, which can be applied to the context of construction project teams using mobile apps. It can provide insights into how mobile apps can improve data management, documentation, and information sharing among construction project teams, reducing errors and delays (Yu, Chávez, Jacobs, & Wong, 2022). By understanding how individuals process and utilise information, mobile apps can be designed to facilitate efficient data management, streamline documentation processes, and enhance information sharing among team members (Yu, Chávez, Jacobs, & Wong, 2022). This can facilitate knowledge sharing among project team members, enabling them to access and exchange information anytime and anywhere (Li, 2014). Mobile apps can also support capturing, sharing, developing, and utilising knowledge, key components of knowledge management (Navimipour & Charband, 2016). This can help minimise construction project errors and delays, improving project outcomes.

COMMUNICATION AND COLLABORATION CHALLENGES AND MOBILE APPS

Unresponsiveness between and among project team members

Unresponsiveness among project team members is a challenge for communication and collaboration among construction managers (Shakeri & Khalilzadeh, 2020). This issue has been identified in several previous studies. The lack of a good communication flow among project participants can lead to misunderstandings and affect performance and reputation (Aziz, Rahim, & Aziz, 2022). In the context of sustainable project management, internal sustainability-related communication is essential, but it is often not organised or perceived in a way that meets the needs of project team members (Sam, Franz, Sey-Taylor, & McCarty, 2022). In collaborative construction projects, project managers must possess the appropriate competencies to foster effective stakeholder interaction and cooperation. Therefore, construction managers should adopt mobile apps to improve collaboration and real-time information-sharing.

Inability to collaborate effectively due to the lack of real-time information sharing

In the construction industry, effective communication and collaboration among construction managers are hindered by the inability to share real-time information (Shakeri & Khalilzadeh, 2020). This challenge arises because of the limitations of the existing project management systems, which primarily focus on document management and administrative tasks (Sam, Franz, Sey-Taylor, & McCarty, 2022). The lack of a comprehensive theoretical platform for defining communication, coordination, and cooperation (3Cs) in construction project management further exacerbates this issue (Farghaly, Soman, & Whyte, 2021). To address this challenge, there is a need to develop collaborative platforms that support communication, information sharing, and task management among the project participants (Alaloul, Liew, & Zawawi, 2017). Such platforms should go beyond traditional document and project management systems and provide features that facilitate real-time

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communication, information sharing, and activity tracking (Annika, 2017). By enabling effective real-time information sharing, these collaborative platforms can enhance communication and collaboration between construction managers, leading to improved project outcomes (Kim, Jung, Kim, Choi, & Chin, 2016). Mobile apps can address this challenge by sharing real-time information, enabling project team members to stay updated about the project's progress and make timely decisions (Abioye, Oyedele, Akanbi, Ajayi, Bilal, Akinade, & Ahmed, 2021).

Poor data management and documentation, leading to errors and delays

Poor data management and documentation in the construction industry can lead to errors and delays in communication and collaboration between construction managers (Shakeri & Khalilzadeh, 2020). This challenge has been demonstrated in several previous studies. For example, a study conducted in the Philippines found that communication and proper data management effectively mitigate construction project delays (Aziz, Rahim, & Aziz, 2022). Another study identified factors such as inaccuracy, misunderstanding, barriers, and project complexity as challenges to communication among construction workers (Akunyumu, Adjei-Kumi, Danku, & Kissi, 2019).

Additionally, a systematic literature review highlighted communication issues such as accuracy, timeliness, distortions, barriers, and misunderstandings among project participants in the construction industry (Sam, Franz, Sey-Taylor, & McCarty, 2022) as culprits to the communication challenges among construction workers. These communication problems can hinder effective collaboration and coordination between construction managers, leading to project delays and decreased productivity. Project managers must recognise the importance of effective communication and implement strategies to improve data management and documentation to overcome these challenges and ensure successful project delivery. Adopting mobile apps can address this challenge by providing efficient data management and reducing errors and delays by providing a centralised platform for project documentation and information (Morrison-Smith & Ruiz, 2020).

Benefits of Mobile Apps in the Construction Industry

Mobile apps can potentially revolutionise the construction industry by addressing the challenges construction managers face in communication and collaboration. The availability of low-cost mobile connectivity via tablets and handheld devices has ushered in a new generation of "mobile first" cloud-based crew-mobility apps that can be deployed, even on remote construction sites, with real-time updates (Agarwal, Chandrasekaran, & Sridhar, 2016). These applications are commercially viable for contractors and project owners of all sizes. The digital collaboration and mobility solutions segment has attracted nearly 60 per cent of all venture funding in the construction technology sector (Agarwal, Chandrasekaran, & Sridhar, 2016).

Mobile apps offer real-time information sharing, enabling project team members to stay updated on progress and make timely decisions (Leonard-Barton, 2014). They also improve collaboration through features such as document sharing, task assignments, and instant messaging (Leonard-Barton, 2014).

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In addition, mobile apps offer efficient data management and reduce errors and delays by providing a centralised platform for project documentation and information (ECLAC, 2021). Yankah, Novieto, Davies, & Adjei (2022) found that mobile apps have been developed to meet the work requirements of most industries, such as manufacturing and services. Mobile BIM applications can help construction managers access blueprints, construction schedules, construction materials, equipment details, and other up-to-date project information on mobile devices (Yankah, Novieto, Davies, & Adjei, 2022). Mobile apps reduce delays by enabling construction managers to gather real-time information, monitor multiple job sites, and enhance project documentation accuracy and flexibility (Bakar, 2022).

Mobile apps can help address these challenges by providing real-time communication and facilitating on-the-go communication among owners, back-office teams, subcontractors, construction managers, fieldworkers, suppliers, clients, and other stakeholders (Yankah, Novieto, Davies, & Adjei, 2022).

METHODOLOGY

The study was conducted through literature research and a subsequent process and analysis of the papers found. The research design was divided into five phases: Previous approach and initial tests; Literature search for construction Apps communication and collaboration; Selection of Apps; Assessment of App and categorisation; and Validating App Functionality.

An examination of the existing literature for construction applications that facilitate communication and collaboration, as well as an evaluation and verification of the functionality of the identified applications, comprise the first phase. To facilitate the literature search for construction-related applications that enable communication and collaboration among construction teams, the initial phase entailed acquiring knowledge about the subject of study and applying that knowledge to formulate key phrases. "Appraisal of Mobile Applications for Communication and Collaboration Among Construction Project Teams"-related literature and studies were utilised to acquire knowledge for the research project. An exhaustive search was conducted for scholarly articles, books, and weblogs. No publications discovered were pertinent to the subject of study. In contrast, fruitful outcomes were obtained from conducting searches on academic journals, app stores, and weblogs.

A correlation between the papers and the research topic was determined by perusing and analysing the titles and abstracts of the academic papers returned by the search. Furthermore, scanning the contents of the resulting weblogs for the academic papers was employed to categorise them. The researchers gained an understanding of the study topic through this preliminary perusal of the broad subject matter. By doing so, potential key phrases were identified and incorporated into search strategies before undertaking the literature search. In Figure 1, the following search strategies were implemented:

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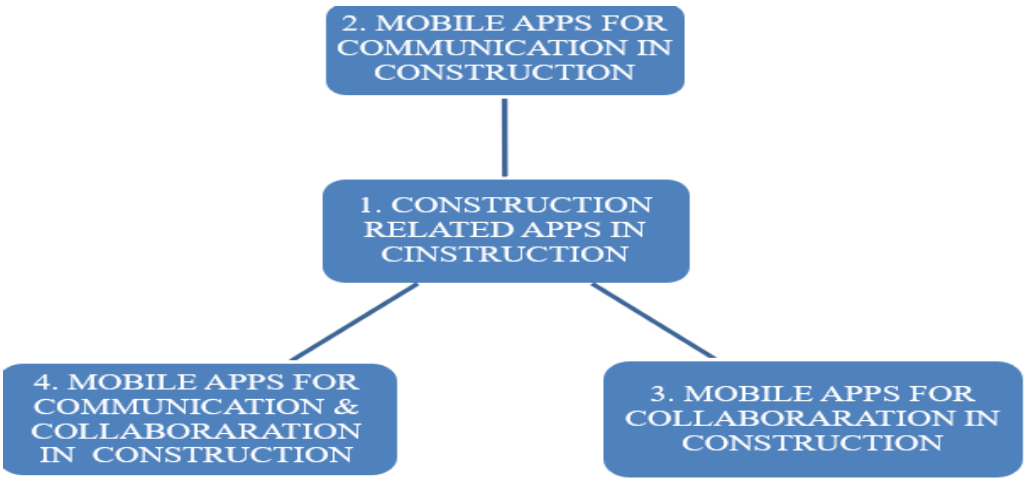

Figure 1: Key phrases developed in Phase One

Utilising the search strategies devised in phase one, the literature searches performed in phase two of this investigation utilised the key phrases to locate a variety of mobile applications that facilitate collaboration and communication among construction teams. They employed these search strategies they had developed to sift through many academic papers and weblogs containing mobile applications designed for collaboration and communication. In the literature search, a variety of databases and app stores were utilised to locate these papers, weblogs, and app stores. The app stores and databases in question are Google.com, academia.edu, researchgate.com, Apkcombo, Google Play, and the Apple Store. The databases were chosen due to their reputation as reliable sources of research papers, books, applications, and blogs covering various subjects. Moreover, inquiries into these sources produced several favourable outcomes.

Each search strategy was derived from a particular key phrase in phase one. As a result, four distinct search strategies emerged. The search strategies comprised functional and task-specific keywords and the operational platforms of intelligent mobile devices (specifically, iOS and Android). The descriptive terms were applied to the "communication and collaboration" of construction teams, to match the construction-related nature of the applications sought. The selection of the operational platforms, namely Android and iOS, was based on their status as the two most widely used mobile platforms globally. These combinations were implemented to enhance the search for construction-related applications that facilitate communication and collaboration among construction teams. The development process of the diverse search strategies employed in the literature search for the applications is detailed in Table 1.

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Table 1. *Search strategies developed the literature search*

Search strategy	Key phrases used	Key phrases combinations
1	Construction-Related Apps in Construction	"Construction Related Apps for communication," "Construction Related Apps for collaboration," Construction Related Apps used by Construction teams," and Construction Related Apps for communication and collaboration among Construction teams"
2	Mobile Apps for Communication in Construction	"Mobile Apps for Communication among Construction teams," "Mobile Apps for Communication among Construction teams onsite'', and "Mobile Apps for Communication among Construction teams offsite''.
3	Mobile Apps for Collaboration in Construction	"Mobile Apps for Collaboration among Construction teams," "Mobile Apps for Collaboration among Construction teams onsite," and "Mobile Apps for Collaboration among Construction teams offsite."
4	Mobile Apps for Communication & Collaboration Among Construction Teams	"Mobile Apps for Communication & Collaboration Among Construction Teams for Android Users" and "Mobile Apps for Communication & Collaboration Among Construction Teams for iOS Users"

Duplicate applications and those taken offline and discovered in newspapers and weblogs were eliminated after the construction-related applications were categorised by name. Furthermore, applications discovered to be incompatible with intelligent mobile devices, including smartphones and tablets, were removed.

Selection of the discovered applications comprised the third phase. The applications above were chosen for the construction project teams' communication and collaboration due to their adaptability and capacity to execute various duties. This phase yielded their market recognition, the significance of collaboration and communication, legibility, and array of capabilities. As the sources (Google Play, Apkcombo, and Apple) prefer to keep these statistics confidential and only provide access to application developers, the number of app downloads included in this study is an approximation. A classification and evaluation of the discovered applications comprised the fourth phase. To ascertain the specific ways, the applications promoted collaboration and communication among the construction project teams, they underwent a comprehensive evaluation. Apps capable of performing multiple tasks associated with collaboration and communication were identified through the initial classification of functions rather than apps using descriptive terms. The word was chosen to describe the functions and duties the applications can perform in the construction industry. Table 2 contains a selection of applications.

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Table 2: *Potential Apps for Communication and Collaboration*

1.	ProProfs Project
2.	Jira
3.	Podio.
4.	Confluence
5.	Yammer
6.	Wrike
7.	Slack
8.	Trello
9.	Asana
10.	Basecamp
11.	InVision
12.	Figma
13.	Facebook Workplace
14.	Nuclino
15.	Flock
16.	Kolab
17.	ProofHub
18.	Hive
19.	Zoom
20.	Zulip
21.	Microsoft Teams
22.	Smartsheet
23.	Monday.com
24.	MeisterTask
25.	Taskade
26.	Todoist
27.	Zoho Projects
28.	Smarty CRM
29.	eTeams
30.	Rainbow Office
31.	ASUS OmniStor
32.	Elenberg Fraser App (EFV App)
33.	Intraboom
34.	Lyria
35.	Zoho Cliq
36.	Microsoft Planner
37.	Chanty
38.	Troop Messenger
39.	Pumble

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40.	Discord
41.	Flowdock
42.	Ryver
43.	RingCentral Video
44.	Brosix
45.	Fleep
46.	Mattermost
47.	Google Meet
48.	Bitrix24
49.	Zoho Connect
50.	Wimi
51.	Miro
52.	HeySpace
53.	Zoho Meeting
54.	Skype
55.	OneDrive
56.	Lucidspark
57.	MangoApps
58.	Avaza
59.	Zoho Workplace
60.	BlueJeans
61.	Google Chat
62.	Rocket.Chat
63.	Project Management-Project 365
64.	Hitask
65.	WhatsApp

Source: authors review, 2023

App functionality validation constituted the final stage of the research design. The functions purported by the app developers to facilitate communication and collaboration among construction project teams were validated and assessed through empirical study articles. This assessment aimed to examine the evidence that substantiates the application's potential. On the contrary, as the developers assert, only 12 out of the 65 applications satisfied the exclusion criteria established to assess the practicality of the functions of the applications using empirical evidence. The functions of the twelve remaining applications are detailed in Table 3 through a comprehensive evaluation process.

FINDINGS

A total of 125 smart mobile device applications utilised by construction project teams for communication and collaboration were identified in the databases that were queried. Subsequently, a filtration process was employed to eliminate duplicate applications mentioned in the discovered

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papers, app stores, and weblogs. Following the completion of the filtration procedure, sixty duplicates were discarded. Consequently, sixty-five construction-related applications that facilitate collaboration and communication among construction project teams persisted. As the developers asserted, however, only 12 of the 65 applications satisfied the exclusion criteria established to assess the functionality of the applications using empirical evidence in Table 3.

The most valuable databases consulted for the investigation were acquired from Apkcombo, Google.com, the Google Play Store, and the Apple Store. This was ascribed to the fact that most scholarly articles and blog posts containing information on applications related to construction originate from Google.com. The search engine Google.com returned 32 construction-related applications that facilitate communication and collaboration among construction project teams. In the interim, the Apple store yielded five applications designed to facilitate communication and collaboration among construction project teams. Once more, ten construction-related applications were extracted from the Google Play store to facilitate communication and collaboration among construction project teams. Additionally, Researchgate.com produced four construction-related applications that facilitate communication and collaboration among construction project teams. Additionally, three applications about construction that facilitate collaboration and communication among construction project teams were retrieved from Academia.edu. In conclusion, eleven mobile applications designed to facilitate communication and collaboration among construction project teams were obtained from the Apkcombo store. Figures 2 to 4 present an analysis of the proportion of applications discovered through each database.

Table 3: *Verified Apps for communication and collaboration*

Apps for Communication and Collaboration		
APP	**FUNCTION**	**REFERENCES**
1. Slack	Bring teams together to plan, schedule, and manage multiple projects on a single platform.	Miller, (2023, January 23), Chasanidou, et al. (2016), https://apkcombo.com/, https://play.google.com/
2. Batiscript Lite	To access instructions and information from other project members	Site Diary (2020)
3. SmartBidNet for Construction	To access a network of subcontractors for easy selection and subletting of works	Barbarosoglu & Arditi, (2016)
4. Trello	Visualisation, tracking, and efficient management of multiple projects without being on-site.	https://trello.com/, Miller, (2023, January 23), Chasanidou, et al,. (2016)

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5. Asana	To templates, keeping projects organised, meeting deadlines, checking project progress, tracking individual tasks, planning sprints, integrating with other tools, creating custom reports, and adding tasks	Baul, (2022, October 7). Project-Management.com. (2022), Chasanidou, et al. (2016), Hess, (2014).
6. Basecamp	To manage projects and collaborate with team members by sharing messages, files and to-do lists	https://basecamp.com/, Hess, (2014), Miller, (2023, January 23)
7. Zoom	To connect with team members across cities and continents in real time.	Miller, (2023, January 23),
8. Microsoft Teams	It allows users to chat, make voice and video calls, and conduct online meetings, making it easier to stay connected and work together on projects.	https://www.microsoft.com/en-us/microsoft-teams/group-chat-software
9. Skype	To make phone calls, host or join video conferences, and send and receive instant messages in one-on-one or group chats.	https://www.softwareadvice.com/video-conferencing/skype-profile/
10. Project Plan 365	To plan project works and collaborate with other project team members without necessarily being on the site or in a meeting.	Google Play;Barbarosoglu & Arditi, (2016)
11. Site Boss	Check the site diary, requests for information, purchase orders, variations, site instructions, etc.	Yankah & Owiredu, (2016)
12. WhatsApp	To communicate information between project team members and share project documents easily	Google Play, iNeosyte (2020)

Source: authors review, 2023

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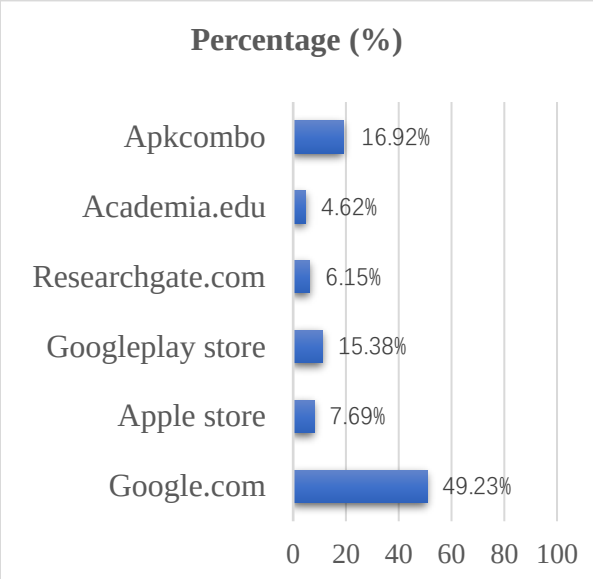

Figure 2: Applications found per database.

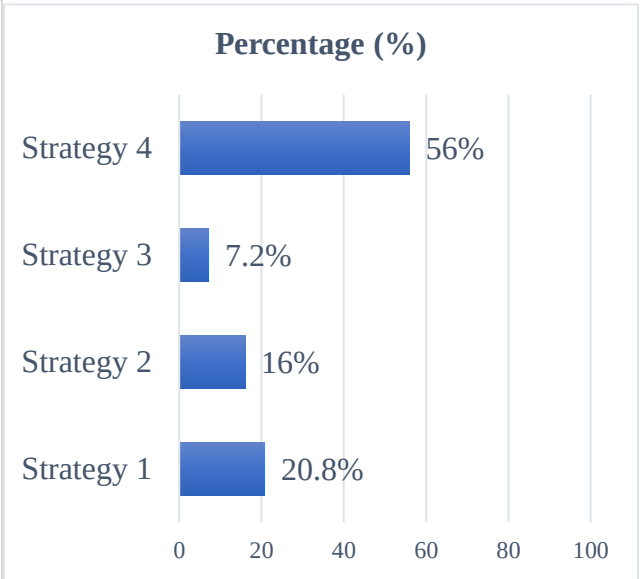

Figure 3: Applications per each search strategy

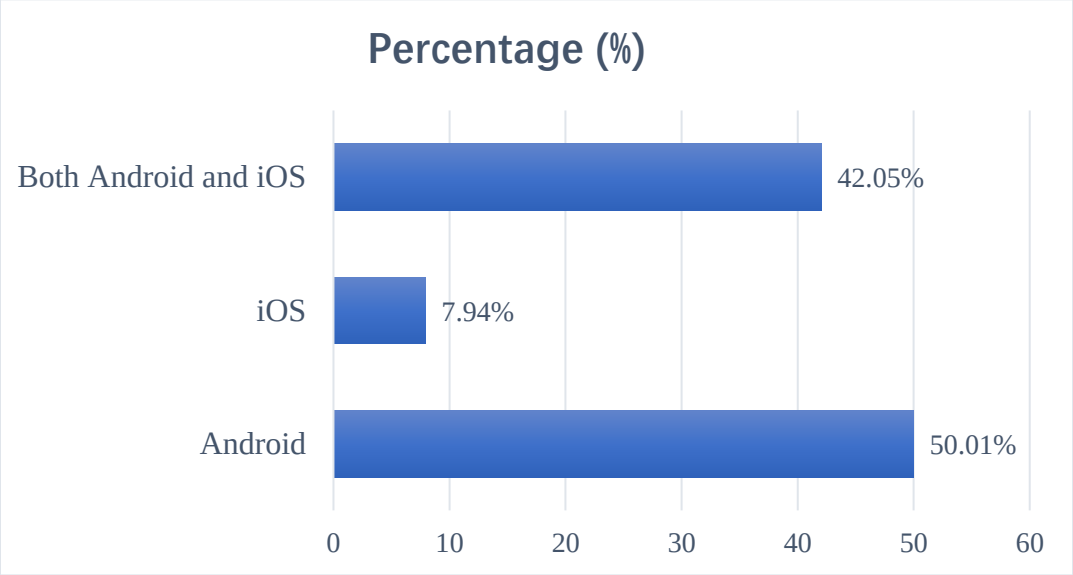

Figure 4. Applications per platform

Capabilities of Apps

The functions of mobile apps extend beyond mere communication and collaboration and can cater to internal and external project parties. After thoroughly examining their capabilities, a list of various functions the apps could perform was compiled. Table 4 provides a comprehensive comparative analysis of the functions that can be performed for each of the 12 applications.

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Table 4: *Apps for Communication and collaboration between internal and external project parties*

		SmartBid Net for Construction	Site Boss	Project Plan 365	WhatsApp	Batiscript Lite	Trello	Asana	Slack	Microsoft Teams	Basecamp	Skype	Zoom
1.	Provides file sharing, real-time communication, and connection with other project management applications.			✓				✓	✓	✓			
2.	To access instructions and information from other project members.				✓	✓							
3.	To communicate information and share documents among project team members.		✓		✓				✓	✓			
4.	To access a network of subcontractors for easy selection and subletting of works.	✓											
5.	To check the site diary, request information, purchase orders, variations, site instructions, etc.		✓		✓	✓							
6.	To plan project works and collaborate with other project team members without necessarily being on the site or in a meeting.		✓	✓			✓	✓	✓	✓	✓		
7.	For managing tasks, collaborating with team members, and tracking projects.	✓				✓	✓	✓	✓	✓	✓		
8.	To track work progress and collaborate with team members without necessarily being on-site.						✓						
9.	For sharing files, videos and other documents with team members.	✓			✓				✓				
10.	For sending messages, files, documents and videos to team members.				✓				✓	✓			
11.	To manage projects and collaborate with team members by sharing messages, files and to-do lists.							✓			✓		✓
12.	For holding instant meetings and communicating with team members from everywhere.											✓	✓
13.	For holding meetings with team members without necessarily being in a site meeting.							✓		✓	✓	✓	✓

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14.	For specific teams, managers and contractors to set up channels for effective communication both within and between departments.		✓		✓				✓	✓		✓	
15.	Critical information is easily available, and all team members are kept data up-to-date.	✓							✓	✓			
16.	Offers chat, video conferences, file sharing, and project management features				✓					✓		✓	✓
17.	It employs a card-based system to keep track of tasks, distribute responsibilities, and assess project progress.	✓		✓			✓				✓		✓
18.	Promotes collaboration and ensures transparency throughout the project's lifetime	✓	✓	✓					✓	✓			
19.	Provides the ability to create projects, assign work, set deadlines, and monitor progress			✓			✓	✓	✓	✓	✓		
20.	Facilitates efficient team communication by enabling real-time updates, conversations, and file sharing				✓				✓	✓	✓		
21.	It gives project managers and contractors a digital platform for logging and exchanging site observations, progress reports, and daily logs, streamlining communication between the parties.		✓			✓							
22.	Project participants can set up exclusive chat groups for in-the-moment discussions, exchange of updates, and problem-solving				✓								
23.	Offers a central location for sharing project files, designs, and bid details, enabling smooth cooperation throughout the tendering process	✓				✓							
24.	Project managers and contractors can organise and work together on project plans, timelines, and tasks.			✓				✓		✓	✓		
25.	Promotes team cooperation by enabling real-time updates and information exchange about projects				✓		✓	✓	✓	✓	✓		
26.	Enables the creation of project-specific discussions, file sharing, task assignment, and			✓	✓			✓	✓	✓	✓		

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	progress tracking between project managers and contractors												
27.	Project participants can speak face-to-face regardless of where they are physically located.				✓				✓	✓		✓	✓
28.	It gives project managers and contractors a digital platform for logging and exchanging site observations, progress reports, and daily logs, streamlining communication between the parties.					✓							
	TOTAL	7	6	7	12	6	6	9	14	16	10	5	6

Source: authors literature review, 2023

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Discussion of the capabilities of mobile apps in construction projects for Communication and collaboration between internal and external project parties

Unresponsiveness between and among project team members

Slack is a popular smartphone application used for team collaboration and communication. It provides file sharing, real-time communication, and connections to other project management applications (Montrief, Haas, Alvarez, Gottlieb, Siegal, & Chan, 2020). Project managers and contractors can establish channels for specific projects or teams, facilitating effective communication within and between departments (Bobhate & Malhotra, 2020). Slack's searchable message archives and alerting tools ensure that critical information is easily available and that all team members are updated (Chatterjee, Damevski, Kraft, & Pollock, 2020).

The Asana mobile app can communicate and collaborate among the construction teams. The app provides technological solutions to support site staff's information needs and enhances collaborative work (Bowden & Thorpe, 2002). It can facilitate efficient communication and collaboration between team members in complex social settings, especially in virtual teamwork environments (Sherratt, Sher, Williams, & Gameson, 2010). The app can accelerate voice and data communication between building construction teams, particularly in small- and medium-sized companies, where technology use and control systems are uncommon (Mauro, 2005). Asana can help overcome the difficulties in achieving optimum levels of collaboration, coordination, and communication in the construction industry, which are essential for efficient project delivery (Amarnath, Sawhney, & Maheswari, 2011). The app includes a collaboration and communication module to create and manage communication groups and control data traffic among team members (Yiu, & Hu, 2006).

Skype mobile apps can be used for communication and collaboration among construction teams. Mobile and wireless technologies, such as web-based project collaboration and mobile facsimile solutions, can significantly improve communication and collaboration in the construction industry (Mauro, 2005; Soetanto, Childs, Poh, Austin, & Hao, 2012). These technologies enable construction site personnel to access accurate and updated project information, which is crucial for successful project completion (Sherratt et al., 2010). Developing innovative learning approaches, such as distance collaboration between students from different disciplines, can also enhance virtual collaboration skills in the construction sector (Kajewski & Alwi, 2006). Information and communication technology, including mobile phones and networked web services, can also accelerate voice and data communication between building construction teams, particularly in small- and medium-sized companies (Venkatraman & Yoong, 2009). Emerging mobile technologies can provide new avenues for improving communication and collaboration among construction teams.

Mobile apps, such as Zoom, can be used for communication and collaboration among construction teams. These apps enable real-time communication and sharing of project information, which are crucial for successful construction projects (Koseoglu & Bouchlaghem, 2008; Mauro, 2005).

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Mobile and wireless technologies can provide construction site personnel access to accurate and up-to-date information and improve project collaboration and communication among all participants (Sherratt, Sher, Williams, & Gameson, 2010). Implementing mobile visualisation technologies can support mobile visualisation applications and collaboration between distributed construction sites and design teams, improving the distribution and clarification of drawings, management of design changes, and resolution of buildability problems (Soetanto, Childs, Poh, Austin, & Hao, 2012). Additionally, mobile phones and networked software can accelerate voice and data communication between construction teams, especially in small- and medium-sized companies, where technology and control systems may be uncommon (Yiu, & Hu, 2006). WhatsApp is useful for boosting communication among project stakeholders because of its simplicity and immediate messaging capabilities (WhatsApp, 2023).

WhatsApp is used as a tool for communication and collaboration among construction teams. It has been found to enhance communication and the development of digital value chains among products, the environment, and business partners (Pozin & Nawi, 2018). WhatsApp group chats have been used to capture and describe students' interactions in online learning, with studies showing differences in message frequency and length between mathematics and business students (Tan & Duzhin, 2023). A software tool embedded in mobile phones and connected to a central control web service was proposed to accelerate communication between construction teams, especially in small- and medium-sized companies (Mauro, 2005). Site staff in the construction industry are ready to adopt modern technology and should be included in future strategies for collaborative systems (Bowden & Thorpe, 2002). Information and communication technologies, including mobile computing and network convergence, can support on-site construction workers and improve their decision-making processes (Ahsan, El-Hamalawi, Bouchlaghem, & Ahmad, 2007).

Inability to collaborate effectively due to the lack of real-time information sharing

The SmartBidNet mobile app is a tool for communication and collaboration among the construction teams. It aims to improve project collaboration and communication by providing construction site personnel with mobile and wireless technologies (Kajewski & Alwi, 2006). The application allows users to access correct, accurate, and updated project information, which is crucial for successful project completion. This is expected to enhance information-rich, real-time communication among team members (Steele, Todd, & Sodhi, 2003). This app addresses the need for collaboration between physically dispersed parties during construction (Li, Zhang, Che, Zhou, Wang & Deng, 2021). It assists in problem-solving between parties on or away from the construction site (Venkatraman & Yoong, 2009). It facilitates collaborative communication between different parties involved in the construction process (David, Harrison., Stuart, Barnes, Biddle, Yoong & Noble. 2004). The app was designed to overcome barriers and issues that hinder the adoption of mobile technologies in the construction industry.

The Basecamp mobile app is a tool for communication and collaboration among the construction teams. It aims to improve project communication and information sharing among the participants

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(Kim, Jung, Kim, Choi & Chin, 2016). The app provides a platform for real-time communication and supports various communication methods and content types (Kajewski & Alwi, 2006). This allows for effective communication, information sharing, and task management, improving efficiency and productivity (Nourbakhsh, Zolfagharian, Zin, & Irizarry 2012). The app also enables easy information sharing and distribution, record-keeping, and tracking management (David, Harrison, Stuart, Barnes, Biddle, Yoong & Noble, 2004). Additionally, the app supports on-site information and document management, making it a useful tool for small and medium-sized construction companies (Venkatraman & Yoong, 2009). The app uses mobile and wireless technologies to provide access to correct, accurate, and updated project information, which is crucial for successful project completion. The app has the potential to enhance collaboration and problem-solving between parties involved in the construction process, both on and off the construction site.

Microsoft Teams is a collaborative working and digital community platform that provides an online space for communication and collaboration among the construction teams. It offers unified conversation platforms, open chats, voice and video calls, content sharing, and meeting solutions for internal and external participants. The platform was piloted in the Distance Learning Unit at Leeds Beckett University to improve team communication, collaborative work, and resource sharing. It has also been used to enhance student engagement and to provide a more accessible learning experience. Communication in Construction Teams highlights the importance of effective communication in construction projects and suggests that successful projects are associated with specific patterns of interaction among team members. The construction industry's drive towards using information and communication technology to enhance collaborative working has also recognised the need to include site staff in future strategies for collaboration systems (Ilag, 2020; Sherratt, Sher, Williams, & Gameson, 2010; Hewson & Chung, 2021; Ireddy & Nungonda, 2019)

Trello is a mobile application that facilitates communication and collaboration between construction teams. It allows for efficient management of data and information inputs and sources, addressing the issue of information overload (Kaur, 2018). The app supports site staff by providing technological solutions that enhance collaborative work and enable them to adopt modern technologies (Bowden & Thorpe, 2002). Additionally, Trello can contribute to effective communication, information sharing, and task management efficiency by supporting real-time communication and collaborative activities among the project participants (Kim, Jung, Kim, Choi, & Chin, 2016). It also leverages mobile computing, speech recognition, and multimedia content to support on-site construction workers and to ensure smooth decision-making processes (Ahsan, El-Hamalawi, Bouchlaghem, & Ahmad, 2007). By equipping construction site personnel with mobile and wireless technologies, Trello enables them to access accurate and updated project information, leading to better project collaboration and communication (Kajewski & Alwi, 2006).

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Poor data management and documentation, leading to errors and delays

The Batiscript Lite mobile app for communication and collaboration among construction teams has the potential to enhance collaborative work and improve project communication (Bowden & Thorpe, 2002). The app can provide site staff with the necessary information to access accurate and updated project information (Kajewski & Alwi, 2006). It can also support the timely collection of information and knowledge during construction, which is crucial for successful project completion (Ahsan, El-Hamalawi, Bouchlaghem, & Ahmad ,2007). The app can assist in problem-solving between parties on or away from the construction site, facilitating a distributed knowledge network and strong personal relationships (David, Harrison., Stuart, Barnes, Biddle, Yoong & Noble, 2004). Additionally, the app can address the pressures faced by the construction industry, such as decreasing costs, improving productivity, and ensuring quality of service and customer satisfaction (Venkatraman & Yoong, 2009). Effective teamwork is encouraged by Batiscript Lite's user-friendly interface and real-time synchronisation features (Batiscript, 2022).

The Project Plan 365 mobile app aims to provide a practical, economical, efficient, and effective information exchange for quality control (Riley,2018). It includes six functional modules: announcement, planning, inspection, implementation, disposal, and service platforms (Jiang et al., 2015). This app was designed to address the challenges of communication and collaboration among project teams in the construction industry (Lam, Wong & Tse, 2010). It recognises the importance of intra- and inter-organisational communication for successful project management (Wu, Liu, Zhao, & Zuo, 2017). The app leverages information and communication technology (ICT) to enhance collaboration and overcome obstacles such as self-discipline, technical support, and system capacity (Boddy, Wetherill, Rezgui, & Cooper, 2008). It also emphasises the need for effective team communication, including formal communication mechanisms, to ensure project success. By utilising the app, construction teams can improve their willingness to communicate, enhance formal communication, and effectively manage task conflicts to achieve project success.

The Boss mobile app was designed for communication and collaboration among the construction teams. It aims to improve project collaboration and communication by providing construction site personnel with mobile and wireless technologies, thus enabling them to access correct, accurate, and updated project information (Kajewski & Alwi, 2006). The app recognises the information needs of site staff and offers technological solutions to support them, contrary to the perception that site staff are resistant to adopting modern technologies (Bowden & Thorpe, 2002). It also addresses the limitations of existing project management systems by providing a platform for real-time communication, information-sharing, and task management (Kim, Jung, Kim, Choi, & Chin, 2016). This application aligns with the trend of utilising mobile technology in the construction industry, offering convenience and efficiency in construction management (Kim, Ok, & Kim, 2017). Research conducted in New Zealand has highlighted the potential requirements and barriers for a successful mobile collaboration tool in the construction industry, emphasising the importance of personal relationships and a distributed knowledge network (David, Harrison, Stuart, Barnes, Biddle, Yoong & Noble, 2004).

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Summary of Findings

The study highlights the potential of mobile apps to revolutionise communication and collaboration in the construction industry, aligning with the overall digital transformation of the sector. By leveraging mobile apps like Slack, Microsoft Teams, SmartBidNet, and Basecamp, construction teams can streamline project management, improve real-time communication, and enhance problem-solving capabilities. Adopting mobile apps in the construction industry can significantly enhance communication, collaboration, and decision-making processes, improving project efficiency and accuracy. Research in New Zealand emphasises the importance of personal relationships and a distributed knowledge network in successful mobile collaboration tools for the construction industry. The functions of the 12 identified mobile apps were thoroughly evaluated, providing evidence supporting their potential for enhancing communication and collaboration among construction project teams**.**

CONCLUSION AND RECOMMENDATIONS

The study concludes that the findings align with the theory that mobile apps have the potential to revolutionise communication and collaboration in the construction industry. The study provides empirical evidence supporting the effectiveness of specific mobile apps in improving project efficiency, real-time communication, and problem-solving capabilities. Additionally, the study acknowledges the importance of personal relationships and distributed knowledge networks in successful mobile collaboration tools. The study contributes to the existing body of knowledge by providing insights into the availability, accessibility, and competencies of mobile apps in improving communication and collaboration within the construction industry.

Practical Implication

The practical implications of this study suggest that adopting mobile apps in the construction industry can significantly enhance communication, collaboration, and decision-making processes. Mobile apps with GPS and tracking functionalities help optimize the use of construction resources, such as equipment and personnel. Remote monitoring enhances project oversight, allows for immediate issue identification, and reduces the need for physical presence at the site, saving time and resources.

Social Implication

Mobile apps facilitate real-time communication with local communities, allowing construction projects to address concerns and involve community members in the decision-making process. Improved community engagement fosters positive relationships, reduces conflicts, and enhances the social license to operate for construction projects. The adoption of mobile apps in the construction industry, when done thoughtfully, can contribute to a more socially responsible and inclusive sector. It not only enhances efficiency and productivity but also addresses societal expectations for transparency, safety, and environmental sustainability.

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Recommendations

It is recommended that small- and medium-sized companies in the construction industry should prioritise using mobile technologies for effective project management. Training initiatives should be implemented to increase site workers' skill level and comfort using these tools. The development of these applications should continue focusing on their interoperability, ease of use, and support for collaboration and communication. Future strategies for collaborative systems should include on-site workers to leverage their readiness to adopt modern technologies.

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