Perceived Productivity Effects of Mobile ICT in Construction Projects

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Abid Hasan, Kumar Neeraj Jha, Raufdeen Rameezdeen, SeungJun Ahn, and Bassam Baroudi

Abstract

The increased affordability of mobile devices, wider network coverage, and better mobile applications have changed the ways communication and information transfer take place in the construction industry in both developed and developing countries. While considerable research has been conducted on the extent of usage of mobile information and communication technologies (mobile ICT) and development of prototype applications in the context of construction projects, less attention has been paid on examining the perceptions of construction management (CM) professionals regarding implications of using mobile ICT. The present study identified different ways in which the use of mobile ICT translates into better productivity in construction projects. A questionnaire survey conducted across the Indian construction industry revealed that the use of mobile ICT improves construction productivity due to four factors: (1) improved communication and information flow, (2) better project execution, (3) improved access to data, and (4) proper defect management. While attributes related to communication and access to information received high rankings, the respondents perceived that the use of mobile ICT has low positive influence on attributes such as cost savings, speed of construction, sustainability, and construction errors.

Keywords

Information and communication technology (ICT) • Mobile ICT • Construction productivity

20.1 Introduction

The construction sector is heterogeneous, highly fragmented, closely regulated, and project-oriented [1]. It attracts a wide variety of people from different cultural and professional backgrounds to work together. Consequently, proper communication between various parties assumes enormous importance in construction projects. Moreover, the success of many information-intensive construction processes is heavily dependent on the timely availability of accurate data [2]. However, the temporary nature of project organizations makes communication a very complex process in construction projects [3].

Construction management (CM) professionals are highly mobile and usually spend considerable time traveling between sites and offices. Since construction projects involve mainly fieldwork, communication and access to information has been problematic and slow [4]. Communication through fixed telephones and exchange of paper-based mails is asynchronous in nature which causes time delays. Moreover, the fixed telephone interactions confine the users to a specific location [5].

A. Hasan (✉) · R. Rameezdeen · S. Ahn
University of South Australia, Adelaide, 5000, Australia
e-mail: abid.hasan@mymail.unisa.edu.au

K. N. Jha
Indian Institute of Technology, New Delhi, 110016, Delhi, India

B. Baroudi
University of Adelaide, Adelaide, 5000, Australia

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On the other hand, CM professionals require on-demand access to information to resolve issues on sites [6]. A clear understanding of on-site information about work tasks and construction resources, and the real-time project data are prerequisites to take right decisions [7, 8]. To achieve this, many construction organizations have adopted mobile information and communication technologies (mobile ICT) during the last few years.

The use of mobile ICT such as smartphones, tablets, mobile applications, wireless connectivity, and cloud computing presents an excellent opportunity to facilitate instant communication and information transfer in construction projects [9]. Due to increased network coverage and advanced software and hardware platforms, mobile devices have become ubiquitous ICT [10]. It is estimated that the number of smartphone users will increase from the 2.6 billion recorded in 2014 to 6.1 billion by 2020 with 70% of the world's population using smartphones and 90% covered by mobile broadband networks [11]. In India, the number of smartphone users have grown to 340 million [12].

Due to this unprecedented growth in the use of mobile ICT, the ways in which communication and information transfer take place nowadays have changed considerably [13]. However, unlike other industries, the implications of these technologies for productivity have not been explored in sufficient depth within the context of the construction industry. This study was conducted to identify the perceived effects of the use of mobile ICT on construction productivity.

20.2 Literature Review

The adoption of mobile ICT presents an excellent opportunity to bring drastic changes in the use of data, information, and knowledge in the construction industry [14]. These technologies can enable CM professionals to access computing and communication functionalities seamlessly regardless of space and time [15]. As a result, smartphones and tablets have become an integral part of day-to-day construction processes. These technologies accelerate fieldwork to improve productivity and allow for less management inefficiencies [16]. In addition, allowing workers to access information from any location can help to overcome the inconvenience of travelling back and forth between the construction site and office. Moreover, these technologies could assist CM professionals in efficient management of remote construction projects [17].

Mobile ICT can facilitate access to unlimited information on the internet, instant correspondence using various applications, and collaboration between different teams using technologies such as audio and video conferencing [18]. Their successful implementation can result in faster decision making, cost savings, reduced project delivery time and reduced impact of the physical dispersion of construction professionals [19]. Therefore, it has potential to improve the field work, on-site information management, and productivity significantly in construction projects [4, 20, 21].

Furthermore, cloud storage provides access to data and other computational services via the Internet [22]. The advantage of cloud services is that documents can be updated easily and processed simultaneously by many users and the new content can be made available immediately [23, 24]. It significantly overcomes the limited processing power and storage capacity of mobile devices by providing a separate computing and data storage resource [25].

Although mobile ICT are becoming more popular in the construction industry, very few studies have been undertaken to examine the implications of the use of mobile ICT for construction productivity from CM professionals' perspectives [26]. There is a need to develop a better understanding of perceived effects of the use of these technologies on construction productivity, especially in the context of developing countries such as India where the uptake of mobile ICT is still low. Consequently, the present study examines various attributes and factors associated with the use of mobile ICT that improve productivity in construction projects.

20.3 Research Methodology

An initial questionnaire was developed based on literature review. The questions were divided into five parts and covered different facets of mobile ICT usage. The first and third sections have been reported in the current paper. The first part of the questionnaire consisted of questions on personal and professional attributes of the respondents. The third part had questions on positive implications of the use of mobile ICT for productivity in construction projects. Whereas, the remaining three parts of the questionnaire covered the extent of mobile ICT usage in construction projects, negative implications of the use of mobile ICT for productivity, and limitations of mobile ICT. The initial questionnaire was administered to six CM professionals who had an average eight years of experience of using mobile ICT in construction projects. The feedback received

from the participants brought attention to few mistakes committed in the self-administered questionnaire. As a result, some changes in the layout and language were performed to make sure that the members of the population interpret the questions correctly. The questionnaire was tested again after corrections in the initial questionnaire by a different group of four experienced CM professionals [27].

The final questionnaire was administered online. The organizations or respondents accounted for the sample survey comprised of the members of the Construction Industry Development Council (CIDC). The CIDC was set up in 1996 by the Planning Commission, Government of India, jointly with the Indian construction industry to take up activities for the development of the Indian construction industry [28]. It is a consortium of construction companies, construction equipment manufacturers, technology providers, and research institutions. Since most of the key organizations in the Indian construction industry are also the members of CIDC, the authors considered CIDC as a credible source for collecting data. It had 117 members at the time of data collection. Of these, 62 organizations who directly undertake construction projects of different nature were chosen as the population for this study. For ensuring the accuracy of the chosen sample representing the entire population, Eqs. (20.1) and (20.2) were used to decide the sample size [29].

$$SS = \frac{Z^2 \times P \times (1 - P)}{C^2} \tag{20.1}$$

where SS represents the sample size for the survey; Z represents the confidence level (1.96 for 95% confidence level); P represents the percentage of selecting a choice, expressed as decimal (0.5 used for sample size needed); and C represents the confidence interval i.e. 0.5. The Eq. (20.1) gives the value of SS as 384.

Correction for finite population:

$$New\ SS = \frac{\mathrm{SS}}{\left(1 + \frac{\mathrm{SS}-1}{\mathrm{pop}}\right)} \tag{20.2}$$

where pop represents 62 construction firms that were members of CIDC. Using Eq. (20.2), the new sample size turned out to be 53 organisations. Moreover, nine other construction companies who were not in the CIDC list were also found suitable for collecting data and thereby, included in the sample. The anonymous questionnaire was finally sent to CIDC member organizations and other companies and after a continuous follow-up for 6 months, a total of 119 questionnaires were received from 61 organizations. However, 14 responses were discarded due to incomplete information. Finally, 105 completed survey responses received from 54 construction organizations were used for further analysis. Table 20.1 shows the details of participants. The data represents a good mix of respondents and organizations with distinct characteristics.

Initially obtained in terms of a five-point Likert scale in which 1 represents strong disagreement and 5 represents strong agreement, responses were stored and analysed using the *Statistical Package for Social Sciences* (SPSS) *version 25* software program. Each of the attributes affecting the use of mobile ICT was ranked based on mean values. The highest mean value indicates the most critical attribute with rank 1, the next most critical attribute with rank 2 and so on. If the mean value is equal, the attribute with lower standard deviation received the higher ranking.

The Cronbach's alpha, α, was calculated to check the scale reliability. The value of α was 0.889, which indicates good reliability of the questionnaire [30]. All the diagonal values in anti-image correlation matrix were greater than 0.5 and hence all the attributes were considered suitable for factor analysis. In the next step, exploratory factor analysis (EFA) was performed for data reduction purposes. The factors extracted using principal component analysis were orthogonal and contained many overlapping attributes across various factors. Therefore, a principal axis factor analysis was conducted on 23 items with oblique rotation. The Kaiser–Meyer–Olkin measure verified the sampling adequacy for the analysis, KMO = 0.814, which is well above the acceptable limit of 0.5 [31]. For analyzing the multivariate normality and correlations between the factors, the Bartlett's test of sphericity was conducted. The value of significance obtained was 0.000 (<0.005) which further represented the suitability of data for factor analysis. Four factors had eigenvalues over Kaiser's criterion of 1 and in combination explained 46.88% of the variance. The scree plot also showed the inflexion point that justified retaining four factors.

Table 20.1 Respondents' profile

Characteristics	Categories	Number of respondents	% of total
Experience (in years)	Less than 5 years	59	56.19
	6–10	26	24.76
	11–15	9	8.57
	Over 15 years	11	10.47
Sector	Residential projects	19	18.10
	Commercial projects	21	20.00
	Industrial projects	26	24.76
	Infrastructure projects	39	37.14
Job title	Site engineer	29	27.62
	Planner	33	31.43
	Construction manager	10	9.52
	Project manager	19	18.10
	Executive	14	13.33
Years of mobile ICT usage in construction projects	Less than 1 year	9	8.57
	Between 1–3 years	27	25.71
	Between 3–5 years	22	20.95
	Between 5–10 years	34	32.38
	More than 10 years	13	12.38
Respondent's company turnover, 2016–2017 (in million INR)	Less than 100,000	44	41.90
	10,0001–500,000	29	27.62
	Above 500,000	32	30.48

20.4 Results and Discussions

Table 20.2 shows the ranking of different attributes based on their mean and standard deviation values. Whereas, Table 20.3 shows the factor loadings after rotation. Due to space limitations, the identified factors have been discussed briefly.

Table 20.2 demonstrates that the use of mobile ICT results in increased construction productivity mainly due to improved communication and better access to information. The respondents perceived that the use of mobile ICT has relatively less positive influence on cost savings, speed of construction, sustainability, and construction errors, as reflected by their relatively low mean values or rankings.

20.4.1 Improved Communication and Information Flow

This factor includes nine attributes that explain improvements in communication and information transfer due to the use of mobile ICT in construction projects. The use of mobile ICT not only improves communication within a team but also between different project teams. Previous studies have also found that the use of ICT in the construction projects results in improved coordination, collaboration and communication processes and faster decision making [32, 33]. By allowing seamless and effective transmission of information, these technologies eliminate the kinds of errors and delays that are inherent in manual approaches [4]. Using built-in cameras, photos and videos from the construction site can be shared with other project team members for an informed discussion [26]. Consequently, the time taken in planning or resolving an issue is reduced considerably which improves construction productivity.

Table 20.2 Ranking of attributes

Rank	Attributes	Mean	Standard deviation
1	Instant flow of information	4.39	0.596
2	Instant access to information	4.33	0.645
3	Improved communication between different teams	4.29	0.600
4	Improved communication within the team	4.29	0.661
5	Better reporting between site and office staff	4.21	0.583
6	Instant accessibility	4.18	0.585
7	Simplified exchange of information	4.14	0.657
8	Access to meteorological data (rain, temperature etc.)	4.13	0.636
9	Ability to capture more data	4.12	0.646
10	Less paperwork	4.11	0.870
11	Increased work flexibility	4.03	0.596
12	Instant inspection reports	4.01	0.612
13	Availability of relevant data on cloud for remote access	3.97	0.713
14	Better response to contractual provisions (e.g. notice of delay within 24 h)	3.97	0.727
15	Faster decision-making process	3.93	0.858
16	Instant clarification/correction in drawings	3.89	0.788
17	Improves working relationship between teams	3.86	0.713
18	Better material management	3.75	0.806
19	Better defect management	3.72	0.753
20	Cost savings	3.59	0.840
21	Increased speed of construction	3.46	0.832
22	Improved sustainability or reduced waste generation	3.43	0.908
23	Less construction errors	3.41	0.817

20.4.2 Better Project Execution

This factor has seven attributes that represent the improvements in execution of project due to the use of mobile ICT by CM professionals. The improper management of materials, drawing errors, and rework have been identified as major causes of poor productivity in construction projects [34]. The respondents also perceived that the use of mobile ICT improves response to contractual provisions by reducing construction errors and providing instant clarifications and updates. Previous studies have found that the construction costs can be reduced by up to 25% through efficient transfer of information between the construction teams [35]. Moreover, these technologies have potential to result in shorter completion time of tasks [36].

20.4.3 Improved Access to Data

The first attribute highlights the benefits offered by mobile ICT in accessing meteorological data which could help in better planning of construction activities. Since most of construction work is carried out in an open environment, the timely information on adverse weather conditions could reduce its negative impacts on productivity. Similarly, the use of mobile ICT can facilitate access to data from anywhere at any time using cloud-based applications. This shift from traditional paper-based to digital-based data management improves productivity in construction projects [26].

20.4.4 Proper Defect Management

This factor explains a variance of 5.212% and has two attributes. The less waiting time between inspection and the report saves considerable amount of time and thereby, results in better management of construction defects. Moreover, the

Table 20.3 Factor profile of attributes associated with the use of mobile ICT

Serial number	Details of factors and attributes	Factor loading	Variance explained (%)
1.0	**Improved communication and information flow**	–	16.370
1.1	Improved communication within the team	0.791	
1.2	Improved communication between different teams	0.771	
1.3	Improves working relationship between teams	0.618	
1.4	Simplified exchange of information	0.563	
1.5	Faster decision-making process	0.544	
1.6	Better reporting between site and office staff	0.531	
1.7	Instant accessibility	0.460	
1.8	Less paperwork	0.441	
1.9	Instant flow of information	0.425	
2.0	**Better project execution**	–	15.733
2.1	Improved sustainability or reduced waste generation	0.805	
2.2	Better material management	0.780	
2.3	Cost savings	0.741	
2.4	Less construction errors	0.581	
2.5	Increased speed of construction	0.570	
2.6	Better response to contractual provisions (e.g. notice of delay within 24 h)	0.539	
2.7	Instant clarification/correction in drawings	0.454	
3.0	**Improved access to data**	–	9.561
3.1	Access to meteorological data (rain, temperature etc.)	0.636	
3.2	Availability of data on cloud for remote access	0.597	
3.3	Increased work flexibility	0.486	
3.4	Instant access to information	0.452	
3.5	Ability to capture more data	0.407	
4.0	**Proper defect management**	–	5.212
4.1	Better defect management	0.672	
4.2	Instant inspection reports	0.476	

information is readily available to make an informed decision rather than a judgement call which eliminates the delays inherent in manual approaches [26]. Using a defect management software, information on construction defects can be promptly recorded and shared.

20.5 Conclusion

Given current popularity of mobile ICT, research into examining the implications of these technologies for construction productivity is highly warranted. The aim of this research was to examine the ways through which the use of mobile ICT improves construction productivity from the perspective of CM professionals. The findings of this study are expected to increase the use of these technologies in construction projects, especially in developing construction markets such as India where construction organizations show reluctance in the uptake of ICT.

The factor analysis highlighted that mobile ICT improves productivity in construction projects by improving communication and information flow, project execution, access to data, and defect management. The questionnaire survey further revealed that the impact of mobile ICT in improving communication and information transfer is perceived as more important compared to its role in improving performance of construction projects in terms of cost, schedule, and sustainability. It seems that the potential impacts of mobile ICT usage on cost and schedule performance of construction projects are yet to be

realized in the Indian construction industry. Considering positive implications of the use of mobile ICT for construction productivity, it is put forth that construction organizations should invest more in these technologies.

The findings of this study must be considered within the context of its limitations. The data for this study was gathered only from CM professionals working in the Indian construction industry. More research is needed to devise measures to enhance the potential applications of these technologies in improving cost, schedule, safety, and sustainability in construction projects. However, despite these limitations, the findings highlight the main benefits associated with the use of mobile ICT in construction projects.

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