Impact of Mobile Tools and Technologies on Jobsite Operations

Salman Azhar
Auburn University
Auburn, Alabama

Andrew J. Cox
US Army Corps of Engineers
Ft. Stewart, Georgia

The construction industry is constantly looking for ways to improve efficiency and productivity on the jobsites. The integration of mobile tools and technologies into construction operations management can help enhance the jobsite efficiency, quality, and productivity. The aim of this research is to gain an understanding of how mobile tools and technologies are impacting current jobsite operations. The required data are collected via interviews and a questionnaire survey. Data analysis revealed that mobile tools and technologies are having a profound impact on the jobsite operations. Other findings indicated that: (1) the most widely used mobile operating platform is the iOS®; (2) the most common applications include photos documentation, punch list, quality control, safety analysis, and scheduling/finance documentation; and (3) the use of cloud technologies is becoming common at the jobsites especially for documents access and sharing, home-office coordination, and quality control. The mobile tools and technologies are found to have a significant impact on the following Key Performance Indicators: quality, site coordination, subcontractor management, site-office coordination, safety, and productivity. The cost of training, hardware maintenance cost, software licensing fee, and connectivity issues are found as main barriers in their widespread adoption of mobile solutions. It is envisaged that with the availability of better and cost effective technologies the adoption rate of mobile solutions will continue to increase.

Key Words: Mobile technology, Construction Apps, Jobsite operations, Productivity, Cloud technology

Introduction and Background

Productivity improvement is one of the main goals of the construction industry (Abdel-Wahab and Vogl, 2011). The industry is constantly looking for means and methods to improve the efficiency and productivity on the jobsites (Chen and Kamara, 2011). The integration of mobile tools and technologies (hereinafter referred as mobile solutions) into construction operations management can help enhance the jobsite efficiency, quality, and productivity. Mobile solutions allow the project managers, owners and other stakeholders to get real-time information on the current status of the project. Using mobile devices while on jobsites, the workers can get instant access to project documents, plans and specifications, and many useful construction applications (aka Apps) for data sharing and analysis. Issues that arise on jobsites can be quickly documented and distributed for resolution in a timely manner. The use of mobile solutions can significantly help in streamlining the entire process and results in a reduction in errors and omissions (Ochoa *et al*., 2011).

The construction industry has always been considered as furthest behind as compared to other industries in latest technology adoption and innovation (Van Hampton, 2011). However, this image is quickly changing due to rapid adoption of mobile solutions into the construction operations, both in the field and office levels. At the end of 2013, there were approximately 13,000 design and construction apps available – a significant increase from 230 apps that were available in 2011 (Yovino, 2013). Two of the main benefits of mobile solutions are time and cost savings (Abaffy, 2011). According to Son *et al*. (2012), the construction industry is information-intensive where the success of a construction project depends on the availability of accurate and timely data. Traditional methods of information exchange on the construction jobsite are labor intensive and require manual interventions resulting in unnecessary and sometimes costly delays. Significant research has been conducted by construction researchers to explore different applications of mobile solutions in construction jobsite operations. Table 1 presents a summary of major research efforts in this domain.

Table 1

Recap of Mobile Technologies and Their Applications in Construction Operations Management

Mobile Technology	Applications
Tablets	• Monitor project progress (Bowden and Thorpe, 2002) • Record quality and progress data on site (Davies and Harty, 2013) • Access design information on site (Davies and Harty, 2013) • Track equipment and material (Lee *et al.*, 2013) • Share and manage project information on site (Ochoa *et al.*, 2011)
Smart Phones	• Communication by calling, emailing or SMS other team members (Leskinen, 2008) • Gather specific construction information based on GPS location (Kim *et al.*, 2013) • Picture documentation and sharing (Abe *et al.*, 2013)
Cloud Technologies	• Easier data sharing between project team members; On-demand access to shared pool of computing resources (e.g. storage, applications) (Jiao *et al.*, 2013a)
Radio Frequency Identification Tag (RFID)	• Track PPE compliance on jobsites (Kelm *et al.*, 2013) • Track workers on site (Abaffy, 2013) • Track and manage materials on site (Lee *et al.*, 2013)
Wearable Devices	• Actual project overlay with 3D models and project information (Jiao *et al.*, 2013b)

Despite the above-mentioned benefits and applications, there are several obstacles to the widespread adoption of mobile solutions in the construction industry. The older generation of construction personnel who have years of experience without the assistance of mobile solutions see this change as a threat rather than a new way of doing business (Abaffy, 2011). There are also costs associated with mobile solutions use on jobsites. These costs include training, software (or Apps), hardware, and maintenance costs. Connectivity can also be an obstacle for sites that are in remote areas (Chen and Kamara, 2011). Even with these obstacles, more and more construction firms are adopting mobile solutions on jobsites as their benefits outweigh the shortcomings. The aim of this research is to present state-of-the-art of mobile solutions adoption in the construction industry and their impact on construction jobsite operations. The research results will be helpful for construction firms that are either interested to implement or plan to increase their level of use of mobile solutions.

Research Objectives and Scope

The research objectives are as follows: (1) to examine the mobile solutions that are most beneficial at jobsites and determine their impact on Key Performance Indicators (KPIs); (2) to identify the best Apps for a construction manager; (3) to examine potential drawbacks of using mobile solutions on the jobsites; and (4) to identify current and future challenges in relation to mobile technology adoption. The scope of this research is limited to mobile solutions applications for jobsite operations although the findings would be equally useful for other project phases.

Research Design

A mixed methods research design is adopted for collecting the relevant data. Mixed methods research is an approach where the researcher mixes or combines quantitative and qualitative research techniques, methods or concepts into a single study (Johnson and Onwuegbuzie, 2004). The major research steps are as follows: (1) the preliminary data were collected via literature search and review. Case studies, research articles, and published reports on mobile solutions for construction were reviewed and analyzed; (2) semi-structured interviews were conducted with five construction industry professionals with 5-8 years of experience in mobile solutions to gain knowledge on various mobile tools and technologies currently being utilized; (3) based on the findings of step 1 and 2, an in-depth questionnaire survey was conducted in the Southeast United States to gather relevant quantitative and qualitative data; and (4) the survey findings were shared and discussed with the same five professionals to draw important conclusions and recommendations. The interview questions are listed in Appendix A while a short copy of the questionnaire is provided in Appendix B.

Results and Discussion

This section presents the results of the questionnaire survey. The feedback collected from the experts in steps 2 and 4 is collectively presented along with the survey findings. The target population consisted of general contractors, sub-contractors and the United States Army Corps of Engineers' (USACE) Southeast construction division engineers. To only approach those organizations that are actively using mobile solutions, the convenience sampling method was chosen. A list of 200 organizations was prepared using several resources such as ENR's listings, AGC and ABC directories, and regional construction magazines. Contacts were made via phone and e-mails to find out construction firms that are using mobile solutions from at least 3 years. The final list consisted of 88 organizations. The questionnaire was distributed on February 12, 2014 via email and responses were collected until March 3, 2014. In total 62 responses were received. There were 7 responses that were incomplete and removed from the analysis. Hence the total valid responses were 55 yielding a healthy response rate of 62.5%. The respondents included project managers (32.7%), project engineers (27.3%), quality control staff (20%), superintendents (7.3%), vice-presidents (5.5%) and USACE's engineers (7.2%). The average construction experience of the respondents was 16 years.

Mobile Solutions' Hardware and Software

The respondents were asked about the mobile technology hardware they typically use at the jobsites. They were allowed to choose more than one response. The results are summarized in Table 2 which indicates that the most commonly used mobile hardware on construction sites are iPads (49.1%) and iPhones (45.7%). Blackberry phones (38.2%), Android phones (32.7%) and Tablets PCs (20%) also seem to be among popular choices. The RFID technology is being used by some firms (9.1%) and its share is increasing as the technology develops. It is not surprising that wearable devices did not receive any response as it is still a new technology that is just making its way to the market. In terms of mobile Operating Systems, 54.3% respondents chose Apple iOS®, 32.6% selected Andriod®, 19% picked Windows® (8.X, RT, Win M) while 10.9% selected other platforms such as Blackberry OS®, Linux®, etc.

Table 2

A List of Mobile Technologies Hardware Used at the Jobsites

Mobile Technology Hardware	Response Count	Response Percent
iPad	27	49.1%
iPhone	25	45.7%
Blackberry	21	38.2%
Android Phone	18	32.7%
Tablet PC	11	20.0%
Android Tablet	5	9.1%
Radio Frequency Identification (RFID)	5	9.1%
Other (laptops, non-smart phones)	4	7.8%
Windows Tablet	3	5.5%
Windows Phone	3	5.5%

Mobile Solutions' Applications in Jobsite Operations

The survey results indicated that the respondents are using mobile solutions for multiple applications as shown in Table 3. The top five applications are site photos (69.1%), punch list preparation (54.5%), existing conditions documentation (47.3%), safety comments/violations recording (40%), and scheduling/finance documentation (30.9%). Other applications include BIM coordination (29.1%), project closeout documentation (27.3%), preparing and managing change orders (20%), and preparing/sending RFPs (18.2%). The interviewees provided the following observations: "… mobile technologies have significantly reduced the amount of documents that would otherwise be needed to brought on site", "…….it enables us to have easy access to contract and design information on site"; "…..it is easier to take and download photos of safety violations and quickly use them to take corrective actions….".

Table 3

A List of Applications of Mobile Solutions on the Jobsites

Applications	Response Count	Response Percent
Site Photos	38	69.1%
Punch Lists Preparation	30	54.5%
Existing Condition Documentation	26	47.3%
Safety Comments/Violations	22	40.0%
Scheduling/Finance	17	30.9%
BIM Coordination	16	29.1%
Project Closeout Documentation	15	27.3%
Tracking Material and Equipment	14	25.5%
Change Orders	11	20.0%
Preparing/sending RFPs	10	18.2%
Tracking Personal Protective Equipment (PPE)	9	16.4%
Other (communication, visualization)	9	16.4%
Employee Attendance/Man-hour Tracking	8	14.5%
User Training/Operation and Maintenance Tracking	5	9.1%

Based on the findings of the literature review, preliminary interviews, and analysis of users' ratings, a list of 205 construction-related apps was prepared. Respondents were asked to first select apps that they have used on the jobsite and then rank order their selected apps. The results of the top 10 jobsite related apps are summarized in Table 4.

Table 4

A List of Top 10 Jobsite Operations Related Apps Selected by the Respondents

Apps Name	Description	Response Percent
PlanGrid	Allows designers and contractors to collaborate using plans, specs and photos	57.4%
PunchLists	Users can import jobsite photos, make notes, and link photos to plans	48.5%
My Dimensions Pro	Allows users to record dimensions of room, building, etc.	45.2%
Snapseed	Photo editing	41.1%
Construction Master Pro	Construction calculator	37.8%
iBluePrint	Allows users to create and export custom floor plans	36.5%
OSHA Heat and Safety Tool	Computes the OSHA risk level for outside workers and suggests safety precautions	32.8%
BIMx	3D communication and presentations tool using BIM	29.7%
Green Pro	Allows users to access and track LEED credits	28.1%
SmartBidNet	Bid management software	26.4%

The questionnaire included a list of Key Performance Indicators (KPIs) which were selected to measure the impact of mobile solutions on the jobsite operations. The respondents were asked to rate how mobile solutions have impacted the listed KPIs. Results are shown in Table 5. The lowest cumulative weighted mean score indicates the most positive impact. As can be seen in Table 5, the mobile solutions have a profound impact on the following six KPIs: quality, site coordination, subcontractor management, site-office coordination, safety, and productivity. The least impacted KPIs are material procurement, project duration, and budget.

Table 5

Impact of Mobile Solutions on Projects' Key Performance Indicators (KPIs)

Key Performance Indicators	Cumulative Weighted Mean*	Standard Deviation
Quality	1.70	0.87
Site coordination	1.72	0.72
Subcontractor management	1.76	0.83
Site-office coordination	1.78	0.8
Safety	1.83	0.91
Productivity	1.83	0.97
Customer satisfaction	2.05	0.87
AE coordination	2.13	0.79
Material procurement	2.17	0.78
Project duration	2.82	0.94
Budget	2.95	1.00

* Likert scale: 1-Certain positive impact; 2-slightly positive impact; 3-No impact; 4-slightly negative impact; 5-certain negative impact

The respondents' answers could be influenced by their age or number of years of experience in the construction industry. For example, the respondents that have been in the construction industry for longer have more experience with construction operations before the mobile solutions hit the industry and they could be less dependent on the technology. Whereas the majority of less experienced respondents could be more "tech savy" and more technology dependent. To find out any possible correlation between the numbers of years of experiences and the mean KPIs scores, a two tailed t-test was performed. For this purpose, the respondents were divided into two groups – group 1: respondents with 10 or less years of experience; and group 2: respondents with over 10 years of experience. The results of the two-tailed t-test are shown in Table 6.

Table 6

Influence of Construction Experience on the Mean KPIs Scores

Key Performance Indicators	Mean (10 or Less Years of Experience)	Mean (Over 10 Years of Experience)	two-tailed p value	Results of "t" Test[1]
Quality	1.47	1.81	.08	p > .05
Site coordination	1.93	1.63	.15	p > .05
Subcontractor management	1.79	1.81	.86	p > .05
Site-office coordination	2.14	1.61	.02	p < .05
Safety	1.79	1.90	.66	p > .05
Productivity	2.00	1.74	.18	p > .05
Customer satisfaction	2.07	1.93	.45	p > .05
AE Coordination	2.20	1.93	.09	p > .05
Material procurement	2.38	2.14	.22	p > .05
Project duration	2.13	2.26	.66	p > .05
Budget	2.69	2.45	.45	p > .05

Note 1: p >. 05 indicates no significant difference (Null hypothesis Accepted), p < .05 indicates significant difference (Alternate Hypothesis Accepted)

As can be seen in Table 6, all but one category has p-values less than .05. This indicates that as a whole there is no influence of age or number of years of experience in the construction industry on the amount of use of mobile solutions. This is surprising – typically when discussing how technology is being used on the construction sites, it is usually assumed that the older generation struggles with latest technology. These results indicate that even the older generations are getting along with the technology and actively using them. Site-office coordination was the only category that did show significant difference in the mean value which indicates that the older generation still likes to use traditional methods to coordinate the site-office activities. These observations were also re-confirmed by the interviewees.

Next question was about the use of Cloud technology. Cloud technology provides on-demand network access to a shared pool of computing resources (e.g., storage, applications) that can be managed with minimal effort (Jiao *et al*., 2013a). When inquired about the use of Cloud technology on jobsites, 44.7% of the respondents answered "yes", 42.6% chose "no", while 12.7% were "not sure". The respondents who were using cloud applications were further asked about its impact on the projects' KPIs. The results are shown in Table 7.

Table 7

Impact of Cloud Technology on Projects' Key Performance Indicators (KPIs)

Key Performance Indicators	Cumulative Weighted Mean*	Standard Deviation
Instant documents access	1.38	0.53
Site-office coordination	1.63	0.68
Jobsite coordination and collaboration	1.67	0.69
Quality control	1.76	0.73
Scheduling	1.95	0.79
Submittals	2.00	0.76
Budget	2.40	0.60
Material procurement	2.40	0.64

* Likert scale: 1-Certain positive impact; 2-slightly positive impact; 3-No impact; 4-slightly negative impact; 5-certain negative impact

As can be seen in Table 7, instant document access, site-office coordination and jobsite coordination are the biggest beneficiaries of the Cloud technology. These results reinforce what was found during the literature review. The literature review showed that cloud computing allows data to be shared more easily between the designer, construction team, owner, and all other parties involved on the project throughout the life of the project (Jiao *et al.*, 2013a). The KPIs that rated well from the survey all fit into the categories of data sharing and coordination.

At the end, respondents were inquired about the barriers in the wide spread adoption of mobile solutions. The results are shown in Table 8 which indicates that the cost of training, hardware maintenance cost, software licensing fee, and connectivity issues are the top barriers. Discussion with the interviewees indicated that most companies have not developed any formalized short and long term strategies to address such issues.

Table 8

List of Important Barriers that are Impacting the Widespread Adoption of Mobile Solutions

Key Performance Indicators	Cumulative Weighted Mean*	Standard Deviation
Cost of training	1.58	0.84
Hardware maintenance cost	1.74	0.72
Software licensing fee	1.78	0.70
Connectivity issues	1.89	0.60
Interoperability issues	1.91	0.76

* Likert scale: 1-No effect; 2-slightly negative effect; 3-Very negative effect

Concluding Remarks

This research study shows that mobile tools and technologies are having a mostly positive impact on the construction jobsite operations. The primary mobile devices that were shown to have the largest impact are smart phones and mobile tablets. The results also indicate that different mobile tools are providing various levels of benefits to the different areas of jobsite operations. Coordination, safety, and quality are areas that are benefiting the most from the use of mobile solutions. It is determined that cloud technology is being used by half of the surveyed companies and the feedback received is generally positive. The primary areas where cloud technology is found to have a positive impact are documents access, coordination, and quality. It is found that most of the companies that are investing in mobile solutions are reaping the benefits. It is however recommended that the companies that provide mobile solutions

to their employees should develop strong training program to familiarize employees with their full functionality and benefits. The cost of training, hardware maintenance costs, software licensing fee, and connectivity issues are found as main barriers in the widespread adoption of mobile solutions. It was identified that the amount of experience that someone has in construction did not significantly influence his/her views about mobile technologies use in jobsite operations. It can be argued that with the availability of better and cost effective technologies the adoption rate of mobile solutions will continue to increase in the coming years.

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Appendix A: Interview Questions

1. What experience do you have on construction projects? What is your experience of using mobile solutions?
2. What mobile technology hardware does your company use?
3. What operating system platform does your company use? Why does your company use this operation system platform?
4. What applications are the mobile technologies used for? What Apps does your company use? Why?
5. In what areas of jobsite operations do you see the most benefits from mobile technologies?
6. Does your company use cloud technology? In what areas on jobsite operations do you see the most benefits from the cloud technologies?
7. What drawbacks do you see to the implementation of mobile solutions on construction jobsite operations?
8. What is the future of mobile solutions in the construction industry?

Appendix B: Questionnaire

1. Which of the following roles do you have the most experience with? Project Manager/Quality Control/Project Engineer/Superintendent/Senior Management/Other (please specify): _____

2. How many years of construction experience do you have? 0-5 / 6-10 / 11-15 / 16-20 / 21 or more

3. Does your company use mobile technologies on jobsites? (i.e., Tablets, Mobile, Phones, etc.): Yes / No / Not Sure

4. What operating system platform does your company use? Please check all that apply: iOS (Apple) / Android / Windows / Other

5. Why does your company use this operation system platform?

6. What mobile technology hardware does your company use? Please check all that apply: Wearable Devices (e.g. Google Glass or similar devices) / Radio Frequency Identification (RFID) / Tablet PC / iPAD / Andriod Tablet / Windows Tablet / iPhone / Andriod Phone / Windows Phone / Blackberry / Other (please specify): _____

7. For what applications are the mobile technologies used for? Please check all that apply: Tracking Personal Protective Equipment (PPE) /   Tracking Material and Equipment / BIM Coordination **/** Scheduling / Finance /Punch list / Site Photos / RFP's / Project Closeout Documentation /
Change Orders / Safety Comments / Violation / Employee Attendance / Man hour tracking / Existing Condition Documentation / User Training / Operation and Maintenance tracking / Other (please specify): _____

8. Please rate the effect/impact of mobile technologies on project Key Performance Indicators below:

Project Duration	1	2	3	4	5	n/a
Safety	1	2	3	4	5	n/a
Quality	1	2	3	4	5	n/a
Productivity	1	2	3	4	5	n/a
Budget	1	2	3	4	5	n/a
AE Coordination	1	2	3	4	5	n/a
Customer Satisfaction	1	2	3	4	5	n/a
Subcontractor Management	1	2	3	4	5	n/a
Material Procurement	1	2	3	4	5	n/a
Site-Office Coordination	1	2	3	4	5	n/a
Site Coordination	1	2	3	4	5	n/a

1 = Certain Positive Impact
2 = Slightly Positive Impact
3 = No Impact
4 = Slightly Negative Impact
5 = Certain Negative Impact

9. Please select the Apps your company use and rank order the 10 most utilized apps: (a list of 205 apps was provided)

10. Does your company use Cloud Technology? Yes / No / Not Sure

11. Please rate below the likelihood of the impact of cloud computing to jobsite operations.

Jobsite Coordination and Collaboration	1	2	3	4	5	n/a
Quality Control	1	2	3	4	5	n/a
Scheduling	1	2	3	4	5	n/a
Budget	1	2	3	4	5	n/a
Instant Documents Access	1	2	3	4	5	n/a
Submittals	1	2	3	4	5	n/a
Material Procurement	1	2	3	4	5	n/a
Site-Office Coordination	1	2	3	4	5	n/a

1 = Certain Positive Impact
2 = Slightly Positive Impact
3 = No Impact
4 = Slightly Negative Impact
5 = Certain Negative Impact

Other (please specify): _____

12. Please rate below the likelihood of how the following barriers affect the implementation of mobile technologies on construction jobsite operations.

Cost of Hardware	1	2	3
Cost of Software and Licensing Fees	1	2	3
Cost of Maintenance and Repair to Mobile Equipment	1	2	3
Cost of Training	1	2	3
Connectivity Issues	1	2	3

1 = No Effect
2 = Slightly Negative Effect
3 = Very Negative Effect

Other (please specify): _____

13. Has your company encountered any other issues related with mobile technologies on jobsites? Please explain.