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Implementation of mobile devices on jobsites in the construction industry

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Abstract

In the construction industry, the use of mobile devices at various stages of a construction project is on the upswing. In the construction industry having accurate information on the fly is essential to make critical decisions in a timely manner and eventually compete in the industry. Construction is witnessing efficient and effective ways of using mobile devices for personnel on a construction site. It is increasingly clear that mobile devices are here to stay in the construction industry because of their ability to improve communication and productivity. In the United States, mobile devices such as tablets and mobile phones are being used constantly amongst superintendents and project managers on construction sites. Large software providers such as Autodesk, are making efforts to improve availability of building information models on mobile devices for jobsite use. In this qualitative research, several end users were interviewed to discover how they are using mobile devices on construction sites. Thematic and content analysis of the interview data was conducted as part of the data collection and analysis procedures of this research. The results reveal that these devices are increasingly effective in enabling site personnel in a myriad of ways. The benefits of using these mobile devices on jobsites will be discussed.

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1. Introduction

Mobile devices in construction were primarily driven by email and text messages that became popular to contractors through any smart phone that had this capability. Since then, technology has improved tremendously and has brought forth impressive products such as the iPad and the Microsoft Surface. These two tablets were first

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presented to the public less than ten years ago. These devices are designed to be thin and light weight, making its everyday ergonomics usable on a construction site. Apple and Microsoft have both designed these tablets to handle and process everything a normal, full-size computer can along with the bonus of mobility and ergonomics. Businesses have immediately jumped on board in the past decade and have started using these mobile devices to help with employee productivity. The construction industry has always been known to be behind in technology on the jobsites, as compared to other industries in the United States [1]. According to most articles, construction companies in recent years started with devices such as the Blackberry phone. Blackberry phones were driven through their accessibility of email and fast Internet connection. Now, Apple has taken the Blackberry's place in the construction field with its advancements in applications for construction with new devices like the iPhone and iPad.

Bedard [2], director at Verizon Enterprise Solutions, suggests, *"In construction, one of the biggest recent developments in project management is the integration of mobile technology"*. Bedard also mentions that [2], *"The tools that help collaborate and eliminate bottlenecks in the three phases of construction- planning, designing, and building- are rooted in tablets, smartphones, and mobile intelligent hotspots"*. Companies may be looking for competitive advantages against competitors, mobile devices seem to be saving time and money on projects and that is an important factor as well. The industry has taken a large step forward with companies accepting mobile devices and using them on job sites. Each year, technology of these devices moves forward with new applications allowing these devices to be useful in several areas of construction management. The idea for construction companies is that they can save time, communicate easier, and cut costs with the applications presented with these devices [3]. Mobile devices should accelerate fieldwork into a place of better productivity and allow for less management inefficiencies. The construction industry is facing usual pressures to decrease costs, improve field productivity, and have a competitive edge in terms of quality of service and customer satisfaction. Recent mobile devices and technologies could be one answer to alleviate these pressures including many other situations such as a software called SmartBidNet, which simplifies the bid process through an online server for subcontractors [4]. Understanding how companies are benefitting and stumbling with these technologies can allow for improvements for the future and open the eyes of the future adopters of this technology. Mobile devices need to be seen as more than a primitive tool with basic applications but also as an aid to solving various construction related processes at different levels of a project such as being used to look at digital plans and 3D models.

2. Literature Review

The construction industry is information-intensive due to numerous pieces of crucial information that need to be transferred and exchanged during the life of a project [5]. Mobile Devices were first introduced to construction sites in the 1990s and contained very primitive features. Currently, with the invention of the iPad and similar devices, the use construction technologies have increased enormously. Some of the larger construction companies in the United States supply all of their project managers and superintendents with mobile devices for construction operations. Construction firms in the U.S. with less than \$250 million in revenue invest about 1.6% of it on information technology, while companies with \$10 billion in revenue only spend 1.1% [6]. These levels of spending on information technology (IT) related resources indicate that construction companies are making major investments in the IT area and may well be using mobile devices in their daily operations.

A survey was released recently found 75% of small to mid-sized construction firms in the United States and Canada have used a mobile device to access work-related information [7]. A critical element in construction is the communication between different workers on a construction site. Before mobile devices, there was a significant problem with interpreting field entries for different areas of a project. Mobile devices enable the worker to collect data in a more structured format rather than on paper forms in which there are high chances of human error. As an example, Skanska Construction developed an iOS application for mobile devices to help manage their active hospital projects across the United States. The application is called iSite Monitor and it measures environmental conditions instantly and communicates to the project members an alert of any issue the moment they emerge. This communication feature through the project devices allows for crucial minutes to be saved with some of the hospitals most at-risk patients [8]. Research conducted about on-site document exchange between high and low level

employees of a construction firm found that a mobile communication network could effectively combine information, experience, and competence to solve specific problems caused by unanticipated events that occur on jobsites [9].

Building Information Models (BIM) is now not only offering opportunities for just construction managers and designers, but also for the clients and owners. Research by McGraw-Hill Construction, '*The Business Value of BIM in North America*', shows that BIM adoption in that region expanded from 17 percent in 2007 to 71 percent in 2012 [10]. BIM in today's construction is playing a large role in preconstruction stages for designing and clash detection purposes. It is also being used on high profile projects to show workers what phase of construction they are currently in and how their work should look once they have finished for each step of the way. Smart- BIM virtual prototypes are being used and tested for interior design purposes. This technology uses a smart board and mobile devices to provide a 3D representation of an interior room. Autodesk, a major player in BIM software has developed new software called 'BIM 360 Field' which allows for mobile management on the job site within a BIM environment.

According to Autodesk, 75% of construction dollars are spent in the field and 25 cents of each dollar spent is wasted. The workers in the field are able to look at plans, models, punch lists and relay information to others through BIM 360 Field. As construction continues, this software is capable of keeping subcontractors and engineers constantly connected and up to date on all activities taking place on the site. Field informational reports created by this software are accessible to managers at any time [11]. The ability to digitally collaborate on a building's physical and functional characteristics strengthens and deepens partnerships between architects, engineers, and the client [5].

One of the major benefits of using mobile devices on construction sites is being able to use RFID technology to improve material management. The existing information systems that mainly run on desktop computers cannot operate efficiently because the materials on construction sites are stored far away from the computers in the office. In recent years, information systems based from RFID were developed to track steel, pipe, and structural components with corresponding mobile devices based on a wireless network [12]. These information systems significantly improved equipment management on construction sites [13]. RFID mobile technologies can also assist in recovering misplaced and stolen materials on jobsites. During the worst of the economic downfall in the United States stolen and misplaced material on jobsites reached an all-time high. The National Insurance Crime Bureau estimates that one billion dollars in metals and equipment is stolen from jobsites each year [2]. Thus, RFID enabled mobile devices connected to company-owned jobsite materials can save a significant amount of money due to companies not having to pay for lost or stolen items.

The literature review for this paper was dedicated to get a better understanding of the ramifications of mobile devices on construction sites. All of the subjects reviewed, from the processes companies are using the devices for to future prophecies, were intended to contribute towards the investigation of mobile device usage on construction sites. In contemplation of the literature review for this paper, mobile devices have shown usefulness through three important aspects of construction; efficiency, financials, and safety. While there were several topics discussed previously on mobile devices, a majority of the topics seemed to address to the ability of mobile devices saving time or money and improving safety on construction projects.

3. Methodology

Research methodology is a system of methods used in a particular area of study according to the Oxford Dictionary Online [14]. Methodology can have a simple meaning as well, being defined as the strategic process of how one goes about conducting research project. Semi-structured interviews with construction managers and information technology specialists of construction companies were used as the primary method of data collection in this study. Semi-structured interviews allow the researcher to explore a topic in great detail and enable a discussion format so that clarifying questions can be asked. This research involved interviews with twelve individuals either on a construction site or in a company office. Research has shown that twelve interviews is an acceptable target for qualitative data collection purposes [15]. The interviewees were all asked the same questions and each interview

was conducted in a time frame of 20 to 30 minutes. The participants in the study were selected based on their knowledge of the subject of using mobile devices on construction sites or were crucially involved in helping others with the implementation aspects of mobile devices. Questions to the interviewees focused on the following themes:

- Various uses for mobile devices on the construction site
- Pros & Cons of using mobile devices in construction
- Feedback from end users about use of mobile devices on the construction site

The analysis of the data acquired through the interviews was conducted using thematic analysis and content analysis. Thematic analysis and content analysis are acceptable forms of data analysis techniques for qualitative data [16]. The interview data was first transcribed verbatim and coded separately for thematic analysis and content analysis. Coding the data separately allowed for the minimization of any bias towards interpreting the data. Both methods were adopted to get a comprehensive understanding of the results of the interviews.

3.1. Thematic Analysis

Thematic analysis is a method for identifying, analyzing and reporting patterns within data [16]. This analysis focuses on the coding, examining, and patterns that occur within the recorded data. The themes of the information are meaningful and are associated to the specific research question. An inductive thematic analysis will be taken in this research meaning that the themes identified are strongly linked to the data themselves [17]. This strategy was chosen because the deductive analysis would entail a pre-existing or a framed theme, which would eliminate some of the unknown themes, derived directly by data. In this approach, if the data has been collected specifically for the research, the themes may bear little relation to the specific questions that were asked of the participants. In addition, inductive thematic analysis is a process of coding the data without trying to fit it into a pre-existing coding frame [16].

3.2. Content Analysis

The quantitative content analysis of a large amount of textual data starts by identifying the frequency common and key words used. Krippendorff [18] defines content analysis as “the use of replicable and valid method for making specific inferences from text to other states or properties of its source”. Through identification of these re-occurring words, coding is used to create categories for providing a meaningful explanation to the researcher. As in the case of thematic analysis, inductive and deductive approaches can be used for quantitative content analysis. In this research, inductive analysis was chosen to be the structure once again, with the themes all being derived from the data. Inductive reasoning was chosen because of its methods of arriving at a conclusion through formulating tentative hypotheses to measure and explore rather than a narrow and fixed approach [19].

4. Results and Analysis

The data analysis was conducted after coding the interview data and then in two distinct but related methods through quantitative content analysis and qualitative thematic analysis of the data gathered from the interviews. Use of these two methods for analysis is intended to reveal all of the critical information behind the context of the information collected through the interviews. The data itself is presented by separating it into various themes as described in the research methodology section. Thematic analysis data is presented by the various unique themes identified in the data. Content analysis data is presented in percentages, by grouping codes by frequency of occurrence.

4.1. Field Uses of Mobile Devices

Understanding how construction companies use mobile devices is an important aspect of this study. The theme of field uses involved the largest combination of questions in the interview, with four questions related to the field uses

of the mobile devices. The questions that were used in this theme were all in relation to how companies were using their mobile devices in the field and the software/applications involved in the day-to-day processes of construction by their employees. In the thematic analysis, the questions lead to three categories namely ‘applications’, ‘software’, and ‘basic functions’ as shown in the Table 1.

Table 1: Field Uses of Mobile Devices – Thematic Analysis

Applications	Basic Functions	Construction Specific
Weather	Default device software	Autodesk BIM 360
Punchlist	Tracking Materials	Procore
Plangrid for RFI's	Photo Documentation	Bluebeam
Web-Based Scheduling	E-Mail	Bela software
Timesheets	Photo Messaging	Latista
PDF Viewers		Carlson for layouts
Visual Conferencing		Prolog

The data revealed that all participants are aware of the new construction software and are using them in a broad and beneficial ways on their projects. The data analysis showed that construction specific software related to BIM was being used, such as Autodesk BIM 360, Latista and Procore. This software have the capability of viewing BIM models, assigning tasks, conducting checklists and using plan rooms for accessing details of a project. The interviewees reported that applications such as Plangrid and PDF Expert are conventional because they allow users to digital files and plans from any location for quick solutions. The data also revealed that several built-in basic functions of the device such as e-mail and camera functions were popular. Other applications used included viewing, editing, submitting data online using the built-in web browser application.

From a content analysis perspective the uses of mobile devices on the field are listed in Table 2. The data revealed that more than half of the participants use applications related to e-mail, file sharing, document viewing, BIM related applications and photo sharing. More than a quarter of them use mobile devices for collision detection using BIM models, punchlists, decision-making apps and PDF annotation apps. Other applications also mentioned by the participants included texting, document storing, 3D modeling and video conferencing apps.

Table 2: Field Uses of Mobile Devices – Content Analysis

>50%	>25%	<25%
BIM 360 (7)	Bluebeam (5)	Texting (2)
Document Viewing (9)	Punchlists (4)	Dropbox (2)
File Sharing (7)	Collision Detection (4)	Bela Software (2)
Email (11)	Decision Making (3)	3D Modeling (2)
Photo Sharing (8)	Applications (3)	Skype (2)

4.2. Pros and Cons of Mobile Devices

One of the objectives of this study is to investigate the benefits and drawbacks to the implementation of mobile devices on construction sites. The data was analyzed using the lens of pros and cons of mobile device usage in the construction site. The questions were in relation to the how participants felt about mobile devices and of their uses in construction. These questions were important because it lead to the understanding of the value participants saw in using mobile devices. This information is helpful in finding the best ways a company could use this device and show

the trial and error that occurred in order to reach success. The results of thematic analysis are presented below in Table 3. The participants described more cons than pros for the use of mobile devices on construction sites. Participants mentioned that mobile devices were useful for viewing and sharing documents, reading and responding to e-mail, improved productivity, promoted paperless processes, provided better documentation procedures, allowed for using augmented reality technologies and allowed for data to be accessed ubiquitously. Among the cons of using mobile devices participants said that workers were distracted by mobile devices and suggested that it could lead to safety issues. Participants were concerned that workers have access to sensitive data that might not be suitable for sharing. Participants observed that an Internet connection is necessary for the data to be synchronized and an Internet connection is not always be available. Participants also mentioned that older workers were found to be reluctant to adopt mobile devices. The cost of apps and bugs in software were also cited as cons for the use of mobile devices on a construction site.

Table 3: Pros and Cons of Mobile Devices in Construction – Thematic Analysis

Pros	Cons
Document Viewing & Sharing	Distracted Workers
E-Mail Reading & Responding	Safety issues
Ubiquitous data availability	Privacy concerns for
Augmented Reality	Internet connectivity issues
Improved Productivity	Data Synchronization
Paperless communication	Sub-Contractor Buy-In
Better Documentation	Older worker reluctance
	Software Bugs
	Cost of Apps

From a content analysis perspective, it was interesting to note that in 2014, there were more cons cited than pros for the use of mobile devices in construction. The results shown in Table 4 indicate that connectivity issues featured prominently among the participants. Participants also said document-sharing apps also featured in more than half of responses. Other issues that featured prominently included issues related to safety, productivity, distraction and subcontractor buy-in.

Table 4: Pros and Cons of Mobile Devices in Construction – Content Analysis

>50%	>25%	<25%
Connectivity (9)	Safety (5)	Construction Friendly (2)
Cons (10)	Productive (4)	Complicated (2)
Pros (6)	Subcontractor Buy-in (4)	Paperless (2)
Document Sharing (8)	Tool (5)	Fees (2)
	Distraction (3)	

4.3. Typical feedback from users regarding mobile devices

Participants were asked about how their workers felt about the use of mobile devices in construction. Thematic analysis of this data is presented in Table 5. The data was codified under the labels ‘Enablers’ and ‘Obstacles’. Participants cited improved productivity, ease of use and ease of communication as some of the enablers of using mobile devices. Participants suggested that these tools required training and there was often not enough time to do

that. They also suggested that there was an attitude of resistance to change among workers and that not all workers used all aspects of the mobile devices.

Table 5: End User Feedback for Mobile Devices in Construction – Thematic Analysis

Enablers	Obstacles
Improved Productivity	Older workers have a steeper learning curve
Ease of use	Lack of time for training
Easier to carry than construction drawings	Resistance to change
Ease of communication	Not everyone needs these devices
Once used to devices, difficult to work without them	Not all capabilities are used by workers
Employees feel enabled	Cost of applications
Saves time	Older workers reluctant to adopt these devices

Content analysis of the data suggests that participants felt positively about the use of mobile devices and that they generally felt enabled by the use of mobile devices, as presented in Table 6.

Table 6: End User Feedback for Mobile Devices in Construction – Content Analysis

>50%	>25%	<25%
Good Reactions (10)	Handy (5)	Training (2)
More Productive (10)	Resistance (4)	"Don't Like It"(2)
Experienced Workers (6)	Efficient Employees (4)	Young Employees (2)
"Like It" (8)	Time (4)	Complaints (2)

5. Conclusions

Mobile devices and their involvement with daily construction methods on jobsites have obvious advantages to companies in the construction industry. The construction industry is pouring more money every day towards construction technologies and applications for the use of these devices. As has been discussed countless times in this paper, the benefits of these technologies is clear and their implementation among jobsites in the United States will only increase as more companies continue to invest to stay on top of its advancements. While a majority of mid to large size construction companies is already sold on mobile devices for their employees, many companies in other sectors of construction still haven't discovered it such as residential and smaller sized contractors. It's imperative for the commercial companies in the construction industry to invest in mobile devices and their software capabilities because of its practicality and competitive edge it conveys.

Mobile devices such as Apple's iPad, have transformed numerous industries such as business, education, and healthcare. Mobile devices have clearly made their appearance and have been found to be resourceful in the construction industry. Mobile devices are extraordinary tools that are being used every day in the construction industry. Their ability to link to the Internet, various project stakeholders can access and share information instantly. These devices are likely to advance in form and functionality, increasing their adoption in the construction industry. Future research must consider some of the drawbacks of using mobile devices as identified in this study, while making improvements to productivity. The research and analysis presented helped achieve a full interpretation and a higher exposure to the uses of mobile devices being used on construction sites. Of all the companies studied, every project utilized mobile devices, but the overall procedures used along with the device were all underutilized with respect to the features each product was capable of achieving. With that said, most of these companies fall under the grey area of usage by in day-to-day operations but not to its full extent. If companies fully invest and follow up on

new software for mobile devices, then construction field management can be introduced to an unlimited amount of innovative and superior quality of communications translating to increased productivity, thus profits.

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