Get Smart:
The Smartphone Construction Management Tool

Thomas Mills
Virginia Tech
Blacksburg, VA

Qian Chen
The Ohio State University
Columbus, OH

PDAs and handheld computers have converged with Smartphones to change the way contractors are able to do their work. This concept paper presents an exploration into the possibilities for an effective and productive structure that uses Smartphone applications to support construction field supervision, reporting, and inspection tasks. The authors note that there are over 252 million US Smartphone users and that Type 2 Smartphones possess the capabilities to be successful as field information management (FIM) tools. Smartphone features are presented as functional aspects of construction FIM. Common field data collection tasks are noted and matched in chart form against user information needs and suitability. From these extracts Smartphone assisted FIM including archived document access, management reports, safety monitoring, punch list management, etc. are stated as suitable and achievable. Future research work including field trials is proposed as a continuation of the work.

Key Words: Field Information Management, Mobile Computing, Smartphone, Construction

Introduction

Contractors need large amounts of information for quick and accurate decision-making. Much of this information is created on the job site; yet many times this data is archived off-site by other jobsite personnel and needed information is not readily available. Zou et al. (2006) quotes previous studies indicating that as much as 65% of project rework is a result of insufficient, inappropriate or conflicting information. Although this information is created by those involved, it is typically generated and stored in remote off-site offices. Thus, some of the problems that result in rework can benefit by availability and timeliness of off-site information access. Point of activity access to critical information is essential in the dynamics of construction management (CM). Now is the time for construction to swap the field laptop for the field based Smartphone. Due to the advancements in Information Communications Technology (ICT) and Smartphone technology much of this information is accessible from remote locations and can be productively used on construction jobsites for field information management (FIM), e.g., project schedules, pay requisitions, safety data sheets, progress reports, etc. through commonly used software applications. Other information, such as CAD/BIM documents, invoice/payroll, etc., is created with unique software applications and then converted into a common reader format, either web-based HTML or PDF for importing into a database archive. Another systemic problem created by using digitally produced and stored information is the issue of software/hardware interoperability. Gallaher (2004) estimates in a NIST commissioned report that inadequate interoperability annually costs the US capital facilities roughly $16 billion in efficiency losses. The authors assert that Smartphone technology and appropriate software tool selections can significantly reduce this cost.

These electronically stored files can be viewed, accessed, and exchanged. This is typically through wired desktop or laptop computer networks. A delay in this process can at times affect the efficiency of the CM enterprise. Additionally, construction sites are commonly

established for limited time periods in locations where a wired telecommunication infrastructure may be limited or unavailable, thus again affecting the accessibility of real-time information. Currently there is an ICT mobility transformation in progress that will affect the manner in which field decisions are rendered and the timeliness with which decisions will be expected.

Many people may find instant information access invasive, it does present business management opportunities to process real time informational transfers using on-the hip wireless Smartphone technology for FIM. Wearable computers, in the form of a Smartphone, are small and powerful. They not only can attach to your belt; they are voice activated and can receive user inputs through a finger using a touch screen interface. Although the authors find the following data astounding, if not inaccurate, the CTIA (2007) estimates that there are over 252 million cell phone subscribers in the US. This is approximately 84% of the 300 million US population count; undoubtedly many people must be multiple subscribers. The authors estimate that a significant number of subscribers have Smartphones of one type or another, with the consumer market dominated by devices being used primarily as a telephone, text messenger and picture viewer.

The construction industry, like many other industries uses a suite of desktop computing applications to assist in CM. Among these applications are spreadsheets, email, contacts list, databases, and custom forms for data collection and manual input into other computerized applications. Construction is commonly performed in remote field locations using many different subcontractors with limited computing availability. On one hand, the lack of mobility and a rugged construction environment limit desktop PCs and laptop computers to field offices. On the other hand, critical construction personnel are issued cellular phones for aid in quickly addressing issues with personnel that are away from the work. Considering the limited field use of laptops and the proliferation of cellular phones, it is conceivable that a Smartphone suite of mobile contracting applications could offer an effective mechanism for improving field-based CM activities. Previous work by Haas et al. (2002), Kimoto et al. (2005), and others have validated the capabilities of PDA handheld devices as CM support tools. To achieve a similar effectiveness for Smartphone it is necessary to establish organizational protocols that extend the Smartphone's functionality beyond call and organizer functions to field data recording and exchange functions. This can be achieved by integrating Windows OS and Windows Mobile OS applications to enhance construction information flows and information management.

Smartphones

In brief, a Smartphone is classified as a multi-purpose wireless phone with voice, email, text message, Internet, and picture taking functionality. This paper presents Smartphones as an ICT tool to improve CM processes. This is significant for several reasons: 1) Smartphones are everywhere on and off the jobsite; 2) there is an abundance of Smartphone FIM applications; and 3) young people entering the workforce are extremely proficient in using Smartphone applications.

The authors address Smartphone strengths, limitations, and provide insights into field solutions that are believed appropriate and if implemented can form an effective mechanism to enhance field based CM practices. The position taken by the authors is that Smartphones, Figures 1a – 1d, offer an effective tool for construction project participants to effectively

contribute to project information flows at the point of management activity, either away from or at the workface.

Figure 1a – Smartphone (Motorola, Inc.)

Figure 1b – Blackberry (RIM Inc.)

Figure 1c– Treo (Palm Inc.)

Figure 1d – iPhone (Apple, Inc)

Due to their compact size and wireless capability, cell phones have become indispensable communication devices widely deployed not only in field force CM, but also in finance and insurance, healthcare, manufacturing, utilities, public safety, and property, housing, and asset management, etc. A quick check of websites at Palm, Sprint, Verizon, or AT&T will show the industry specific investment focus that each of these wireless service providers are targeting. Extracts from *Smartphone 2007* indicate that over the next five years Smartphones will grow as laptop replacement computers and become the mobile computer of choice (In-Stat, 2007). By investigating the limitations of Smartphone characteristics, software applications, desktop interoperability considerations, and field information needs and solutions in the construction industry, the authors propose an example strategy for the utilization of Type 2 Smartphones.

Figure 1a through 1d are indicative of the different types of Smartphones. Figure 1a is the classic Type 1 Smartphone. This is a small screen phone predominantly used for voice calling and text messaging. Figures 1b and 1c are the dominant Type 2 Smartphones. Figure 1b is a Blackberry that is primary a cellular phone with strong email functionality. Figure 1c is a Windows Mobile OS that allows synchronization with Windows OS desktop applications. Figure 1d is the iPhone which is used for voice calling and music and video entertainment. Table 1 provides information on additional features and functionality.

Smartphone Characteristics

Smartphones typically refer to cellular telephones that couple voice functionality with a broader range of computer functionality, including contacts, calendars, email, text messaging, digital photography, and Internet browsing and the more robust Type 2 Smartphone will include specialized functionality through built in or off the shelf applications. These devices can be used to manage personal information (e.g., contacts, calendar, notes and tasks), collect and capture data, exchange information either locally or remotely by sending e-mails and messages, and access Web-based databases. Smartphones can typically be characterized as one of three types, referred to in this paper as Type 1, Type 2, and Type 3. This paper will focus on Type 2 Smartphones as they offer a greater opportunity for Smartphone assisted

construction field management. Table 1 provides a general description and basic features of the three types of Smartphones.

Table 1 – Smartphone types, description, and features

Type	General Description	Basic Features
1	Cell phones with limited data processing capabilities. Their main purpose is voice call functions. This type of Smartphone (see figure 1a) features a 1.25" x 1.5" view screen and is the most common Smartphone on the market today.	• Voice call • Email • Appointment calendar • Text messaging • Limited Internet capability • Contacts list • Picture taking
2	A highly advance and more robust device that is slightly larger than Type 1. This type of Smartphone typically possesses an onboard QWERTY keyboard and a 2.5" x 2.5" viewable color touch screen. Type 2 Smartphone is commonly known as a Blackberry or Treo (see figure 1b and 1c), and unlike other Smartphones has advanced functionality that can facilitate and expedite field data collection, data exchange and remote communications among participants. This capability will ultimately enhance on-site FIM and project productivity.	• All Type 1 features plus: • QWERTY keyboard • 240 x 240 pixel touch screen • Voice activation functions • mobile computer OS • desktop synchronize • Bluetooth communication • Memory storage card • Audio/Video playback • PDA like functionality • Spreadsheet and word processing software
3	The iPhone, an innovative entertainment based wireless phone with a larger touch screen. This product is targeted at a consumer based multimedia entertainment market (see figure 1d). Future developments of this device will, without questions, provide improvements in multimedia field data collection and presentation.	• Voice call • Audio and Video playback • 480 x 320 pixel touch screen

Type 2 Smartphone Market Penetration

Market penetration is introduced to show the extent to which Smartphones have penetrated both the personal and business world and created the opportunity for construction FIM. Type 2 Smartphones were introduced into the market in 2004-05 as a convergence of the personal digital assistant (PDA) and the wireless cell phone. These phones had an early identity crisis because users were uncertain if these phones were PDAs or telephones. The three competing Type 2 Smartphones included different operating systems, Windows Mobile OS, Palm OS, and Research in Motion's (RIM) proprietary email services. There was a shakeout period that saw several PDA manufactures attempting to integrate wireless communications and PDA functionality but it was poorly received due to the user's perception of device size. Simultaneous with the rise in Smartphon sales, the sales of PDAs declined. This is attributed

to the inclusion of a telephone on a smaller device with the same software functionality as a PDA. In effect the user got a smaller and smarter wireless device.

RIM was able to quickly introduce and market the Blackberry, a specialty phone with wireless email access in a reasonably slim line format, eliminating the bulkiness of the PDA phone. The business community quickly latched onto this device and the need for wireless email. RIM now counts over 12 million users worldwide. In addition to voice communications, the Blackberry's primary user focus is a wireless email device, a personal organizer, and an instant messenger. RIM's latest 2007- 08 model, the Curve, has email, web browser, text messaging (SMS and MMS), instant messaging, organizer applications, Bluetooth, mapping and phone as well as a two megapixel camera, enhanced multimedia and expandable memory (Research in Motion Limited, 2007). Although these devices lack touch screen functionality they are able to interface with typical office text and spreadsheet applications, and other office productivity suites, e.g., Microsoft Exchange and Lotus Notes.

Simultaneous with RIM's development of the Blackberry, Palm Inc. has been able to leverage Palm OS and in 2006 the Windows Mobile OS into the Treo device (Figure 1c). Based on extracts from Palm Inc. Annual Report (2007) there have been over 8 million Treo's sold since 2006. This sales volume, along with Palm Inc.'s long term market strategy seems to be constrained by manufacturing capacity. This may be insignificant as other major manufactures such as Samsung, Motorola, and Nokia, etc. are also marketing Type 2 Smartphones based on Windows Mobile OS. In addition to the standard Type 2 Smartphone features, the Windows Mobile OS devices also feature a backlit lighted touch screen, built-in Bluetooth, voice commands, Mobile Excel, Word, and PowerPoint, including file synchronization with their desk or laptop counterparts through an Active-Synch application.

Thus as 2007 closes the Type 2 Smartphone market penetration can easily be in excess of 20 million active users. If user growth over the past two years is an example of future growth it is conceivable that by the end of 2008 there can be as many as 35 million Type 2 Smartphone users worldwide. Through the pervasiveness of Type 2 Smartphone the construction industry is primed to augment field data collection with wireless wearable personal computers.

FIM Using Wireless Handheld Computers

This paper builds upon previous work done by others that focuses on using wireless mobile computing for FIM. Table 2 summarizes the results of Bowden et al.'s work in field data application. Their work also offers three benefits that accrue from using mobile ICT in FIM. These benefits are 1) improving efficiency of data capture, 2) improving access to data, and 3) reducing errors and improving data integrity (Bowden et al., 2005).

Table 2- Most common FIM tasks and most useful documents recording types (from Bowden et al., 2005)

Most common FIM data collection tasks		**Most useful FIM recording document types**	
Completing data collection forms	25%	Drawings	24%
Dealing with correspondence	18%	Data collection forms	12%
Viewing and reviewing drawings	13%	Correspondence	8%
Reading and writing specifications	6%	Progress information	7%
		Specifications	7%

A fourth benefit that can be derived from mobile ICT and specifically Smartphone aided CM is its ability to enhance team collaboration. Enhanced team collaboration is the primary purpose/outcome of making project information readily accessible. In this role the Smartphone becomes an essential field tool to bridge the gap between workface activity and remote information resources. Haas et al. (2002) support this position through their findings that mobile devices, PDAs, can indirectly increase productivity by directly decreasing the amount of support work and idle time. By considering previous studies and reviewing the tasks and the document types from Table 2, the authors' position is that handheld computing, particularly Smartphones, can effectively assist FIM by directly interfacing to remove the time/distance barriers between workface tasks, the point of management activity, and information access.

Haas et al. (2002) also note that to achieve effective productivity improvement the functionality limitations of using handheld devices, particularly PDAs, must be overcome. Among the limitations involve features such as screen size, screen visibility, processing capability, and input method. For this reason *viewing and reviewing drawings*, the most common FIM data collection task, becomes a particularly weak application for Smartphone assistance, yet this application may still be useful by adjusting the level of detail needed to assist a particular task, e.g., simple room location identification via symbol. Haas et al. (2002) also address the suitability of various work activities matched to mobile computing FIM support.

Thus to effectively engage Smartphones as a CM tool an investigation and analysis of the most advantageous applications applied to FIM activities is needed. Haas et al. have validated that two of the more appropriate FIM activities that handheld computers including Smartphones can effectively be used for are punch list and material tracking (Haas et al., 2002). Kondratova (2004) has conducted promising research in FIM using Voice*XML* and voice activated inputs operating on Type 2 Smartphones within noisy environments to overcome some of the deficiencies inherent in Smartphones. The research indicates that Florida Power & Light are using this technology on Smartphones to assist remotely located field restoration crews. Some of the inherent problems of integrating Smartphones can be mitigated with studied consideration for task activities and appropriateness of Smartphone features and limitations. Park and Chen (2007) have conducted some interesting work on Smartphone adoption in the health care industry and noted that a user's perception could contribute to adoption of new technologies and better help avoid the structural implementation problem and reduce the time lag for tool adoption. Their work also explores how social influence affects adoption of technology, particularly Smartphone usage and the purpose of usage. Thus once the industry figures out how to use the Smartphone for productivity they will infect their organization. It is not difficult to comprehend that many youth are able to navigate Smartphones with lightening speed and are also able to easily enter

20-30 words per minute, quite possibly faster than field personnel who type on a normal sized keyboard.

There are several successful examples of Smartphone implementations that are used to assist field based CM. For example, it is reported that K. Hovnanian Homes has accrued an annual savings of 15,000 labor hours and $750,000 by integrating into twenty Blackberry Type 2 Smartphones a suite of production planning, inspection, and scheduling applications. This is being done by using several simple but powerful applications based on electronic forms and simple user inputs for task scheduling, site completed, wirelessly transmitted punch lists, and inspections (Moore & Chard, 2006). Another example is the success that Webcor Construction has experienced using an off the shelf Smartphone punch list application that wirelessly synchronizes with its more robust desktop version (Webcor Builders, 2005).

Conclusive Smartphone Functionality for FIM

Building upon previous research in field information management (Haas et al., 2002; Mead, 2001; Tenah, 1986), the authors have categorized in Appendix A FIM functions, user roles, input levels, interoperability with desktop software, Smartphone applications, and suitability of Smartphone assisted FIM. Many of the identified software applications are generic in nature and are resident within Type 2 Smartphones or can be added via third party vendors. The data has not been empirically tested but is hypothesized based on intimate operational knowledge of both Smartphone capabilities and FIM. The intent is to provide an opportunity for studied insight, stratification, and operational selection for continued research into how a user customized Smartphone can assist field personnel in collecting needed field data, then auto-reporting of collected data into operational and simultaneously archived management reports, or via electronic distribution by beaming, via Bluetooth, Infrared, faxing, e-mailing, or wirelessly posting the information from the Smartphone for access by other parties.

The question that must be answered by each organization that desires to Get Smart by implementing Smartphone assisted CM is what activities and applications are most conducive to improving field performance. By extracting insights from Tables 2 and 3 and Appendix A the reader can begin to analyze an approach. One line of attack is to use Table 3 and identify what functional informational needs are suitable for Smartphone assistance. From Table 3 and Appendix A it is apparent that archived data with minimal user inputs, i.e., used in a reading format, such as government and safety regulations, labor agreements, subcontracts, etc., has a high suitability. The reader can then continue to review Appendix A for generic applications, e.g., PDF reader, forms, or other software that can meet the tasks associated with a field function. So the low hanging fruit in Smartphone assisted construction FIM is to select those functions that require minimal inputs and are normally associated with read only functions, e.g., specification review, scope requirement, contract, inspection results, etc. Once a user gains familiarity with Smartphone limitations including screen size and input methods they can move to a higher level of involvement, one that requires some user inputs. These may be as simple as interfacing with forms using drop down menus. These functions include labor hour management, production tracking, safety monitoring, punch lists, etc. Appendix A offers additional insights into what these functions are and what generic applications can apply. Other field functions such as image capture which is an appropriate and suitable application require a higher level of manipulation but can be quickly implemented by an experienced user. This involves opening several applications to open the camera application, take the picture, select the recipient, input text, and then email the picture. Thus according to

Appendix A the function is rated with medium suitability due to its higher level of interoperability. This is a bit more transparent and then it appears as the three applications are frequently interlinked through the Smartphone's built in picture taking software.

Users can approach the use of the Appendix and Table 3 as they wish to reinforce their comprehension of FIM tasks and how they employ their workforce. For example, users can use the rankings to assess the top user informational needs and start there for a path to implementation.

Table 3 is an extraction of information needs from Mead (2001), who has adapted this information from Tenah (1986). The information is presented to give additional insight into what types of information are needed and the levels of organizational demand for the information. Using Mead's data ranking the information was categorized by 1) identifying data that is dynamic in nature and therefore requires continuous updating and 2) identifying information that is generally static in nature and can be extracted from an archived database by a Smartphone application. According to this data analysis the suitability of Smartphone applications is hypothesized. If the results of Table 3 are accurate then a majority of the information needed by the organization is accessible and usable by a Type 2 Smartphone. Information that may not be suitable is detailed information such as drawings, which are poorly viewed on a 2.5" screen, and detailed schedules and budgets, which require extensive navigation and are not well suited for search filters.

Table 3 – Industry informational needs and data suitability for Smartphone Assistance

Functional information need	**Rank of user access need**	**Data condition**	**Suitable**
gov. regulations	4	archived	Yes
labor agreements	6	archived	Yes
subs & vendor contact lists	7	archived	Yes
safety regulations	9	archived	Yes
contracts	12	archived	Yes
historic cost data	14	archived	Yes
scopes of work	17	archived	Yes
test reports	18	archived	Yes
purchase orders	19	archived	Yes
invoices approvals	20	archived	Yes
change orders	22	archived	Yes
cost summaries	1	dynamic	Yes
schedule summary	2	dynamic	Yes
procurement status report	10	dynamic	Yes
field labor costs	11	dynamic	Yes
performance reports	13	dynamic	Yes
production reports	15	dynamic	Yes
critical item status	16	dynamic	Yes
contract documents	3	archived	Some
back charges	21	dynamic	Some
submittal, shops	23	archived	No
detailed project budgets	5	dynamic	No
detailed project schedules	8	dynamic	No

Future Research Work

The Type 2 Smartphone is a viable wireless FIM tool. It possesses the ability to satisfy at-the point of activity, e.g., in the field, on the road, or in a meeting. Construction based FIM functions are shown in Tables 2 and 3 and Appendix A. The work described in this paper is hypothesized and supported by the literature and other researchers' work in handheld mobile field computing. Additional field research needs to be done to validate this research hypothesis.

One of the first tasks to validate the hypothesis that Smartphones are a viable FIM CM tool is to survey the industry to determine the extent of Smartphone availability. This can be followed by field trials to establish basic operational functions, and then continued with the development of a protocol for prototypical applications and for software to enhance these applications. It is anticipated that the following questions will be pursued.

- Who are the construction field Smartphone users?
- What devices and software applications are used?
- At what frequency are various applications being used?
- What are the user information needs and at which level do needs coincide?
- What solutions and in which level of interoperability can Smartphone provide?
- At what level is performance enhanced?

The results will further explain and support the arguments made above and the positions taken. It should validate and enhance Appendix A as a tool for selecting Smartphone tools to aid field and office functions. It should help disclose what the best solutions are concerning the implementation of Smartphone in the construction field and should begin a process of implementing a formal protocol for FIM using Samrtphones in construction.

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Appendix A – Smartphone FIM Categorizations and Suitability

Function	Smartphone Primary FIM User						Input Level	Interop. Level	Smartphone Application	Suitability of Smartphone Implementation
	Exec	PM	Super	FE	Foreman	Crew				
MSDS Management			√	√	√		Minimal	High	PDF Reader; web	High
QC Inspection				√	√		Minimal	High	Forms	High
Schedule Review	√	√	√	√	√		Minimal	High	Project; Primavera	High
Sub & Vendor Lists		√	√	√			Minimal	High	Call; Contacts; Text; Email	High
Critical Items Review			√	√	√		Some	High	Forms; Image capture	High
Field Data Collection				√	√	√	Some	High	Voice Memo; Custom DB; Forms; Image Capture; Web	High
Labor Hours Mgmt.				√	√	√	Some	High	Fxcel; Custom DB; Forms	High
Maintenance Inspection					√	√	Some	High	Forms	High
Material Quantities				√	√		Some	High	built-in calculator; Excel; Forms	High
Production Tracking			√	√	√		Some	High	Excel; Custom DB; Forms	High
Project Collaboration	√	√	√	√	√		Some	High	Call; email; text; image capture; web; PDF	High
Punch List			√	√	√	√	Some	High	Forms	High
Safety Monitoring			√		√		Some	High	Forms; Custon DB; Image Capture; Word	High
Material Tracking				√	√	√	Some	Medium	Bar code; Excel; Forms	High
Document Review		√	√	√	√	√	Minimal	High	PDF; Pocket-CAD	Medium
Image Capture			√	√	√		Minimal	High	Built-in camera jpg image capture	Medium
Purchase Order		√	√				Minimal	Low	Call; Web; Forms	Medium
Estimating				√			Some	Medium	Excel; Custom DB; Forms	Medium
Schedule Update				√	√		Some	Medium	Project; Primavera	Medium
Cost Control	√	√	√				Some	Medium	Excel	Low
Progress Reporting	√	√	√	√	√		Significant	High	Word; Excel; Project; Primavera	Low
Record Drawings			√	√	√		Significant	Low	PDF; Pocket-CAD	Low