# S18-6
# THE USE OF MOBILE COMPUTERS FOR CONSTRUCTION PROJECTS

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**ABSTRACT:** When construction engineers perform their work in the jobsite, they have to record as-built conditions in the project log (Data Collection). On the other hand, the engineers often have to refer to the construction documents when necessary at the job faces (Data Access). The practice of *Data Collection* and *Data Access* in the jobsite can be greatly enhanced by utilizing mobile computing with wireless communications. In this paper, two cases of mobile computing applications for construction field management are presented; Mobile Specifications System and Mobile Data Collection System. The demonstration of the process for developing two mobile applications is the primary purpose of the paper. The problems and issues involved with adopting mobile computing for construction field are also presented. The simple information framework for mobile computing has been also proposed as an outcome of the research. As for development tools, readily available relational database and wireless network have been used. The use of commercial mobile broadband was examined for data communication where local area network is not available.

*Keywords: Mobile Computing, Data Collection, Construction Specifications, Project Management*

## 1. INTRODUCTION

Construction project engineers perform the majority of their daily tasks in the field. They monitor the progress of work while keeping track of available resources such as materials and workers. Due to the mobile nature of their tasks, the engineers would take a great benefit from utilizing mobile devices to communicate and exchange information. Walkie-talkies, wireless phones, and BlackBerry® units are the examples of such devices that are widely accepted in construction projects.

Although the wireless voice communication devices proven to serve the purposes, there has been a great needs for the capability of a higher-level information exchange between jobsite engineers and the pool of the project information. Lately, several mobile computing applications have been developed and adopted successfully by many construction projects. Mobile computing for construction becomes an important part of the success of the project.

On the other hand, there exist several barriers in adopting mobile computing for construction. The nature of construction projects being diverse, large and dynamic, generic software often would not properly handle extensive and various information and data. Not many mobile applications exist for use in construction projects.

In this research, two cases of mobile computing applications are presented; a Mobile Daily Report System and a Mobile Specifications System. Each was developed using consumer-marketed hardware and software with minimal or no programming. They demonstrate a possibility of developing and using mobile computing without extensive amount of development efforts. These systems are the examples of developing software quickly and as needed to accommodate specific requirements of each project.

## 2. LITERATURE REVIEW

There have been several research works related to construction mobile computing. A field data collection system for handling daily reports named "Digital Hardhat" [5] was developed using ruggedized tablet PCs. It proposed the possibilities of using mobile devices in the jobsite by presenting an operable software application on an ad hoc network environment.

The viability of mobile computing heavily depends on the stability of network system. However, due to the rapid improvement in the wireless network environment, the impact of network related issues have been diminished. It became more critical to establish compatibilities among different hardware platforms and data structures. Peňa-Mora, et al. [3], Aldunate, et al. [1], and Reinhardt, et al. [4] proposed computing frameworks for communication among various mobile and non-mobile devices.

Many on-site daily reporting systems are developed and currently well in use in many jobsites. A daily reporting system that is enhanced with real-world applicability was developed by Chin, et al. [2] Chin's "Generate-Select-Check Based Daily Reporting System" presented an information framework that can support consistency and efficiency of task information

management by instantly generating a report which requires simple user input.

The U.S. building construction projects uses CSI (Construction Specification Institute) Masterformat™ for technical specifications (specs) of their construction documents. The traditional Masterformat™ categorizes work items into 16 *Divisions* and 5-digit *Sections* under each *Division*. The new 2004 Masterformat™ now adopts 50 *Divisions* and 6-digit *Sections* although the majority of the *Divisions* (i.e. *Divisions* 3 – 14) remains unchanged. In this research, the traditional Masterformat™ was elected for the development because it was the vastly accepted one at the time.

Division 1 General Conditions
Division 2 Site Construction
Division 3 Concrete — Level 1
03100 Concrete Formwork
03200 Concrete Reinforcement — Level 2
03300 CIP Concrete
03310 Structural Conc.
03350 Concrete Finish — Level 3
Part I General
Part 2 Products
Part 3 Execution — Level 4
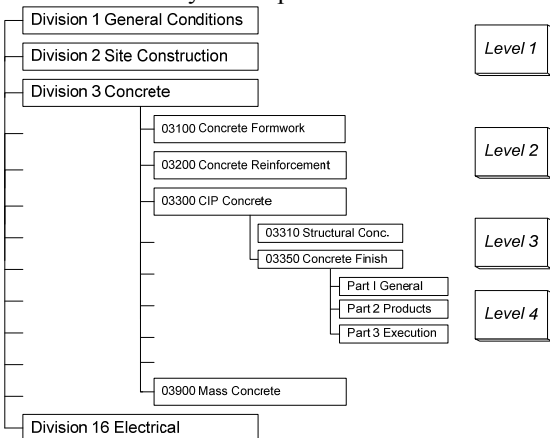03900 Mass Concrete
Division 16 Electrical

Figure 1 shows the hierarchical 3-level structure of Masterformat™. In addition, each Level 3 item consists of three parts, *General, Products, and Executions* (i.e. Level 4).
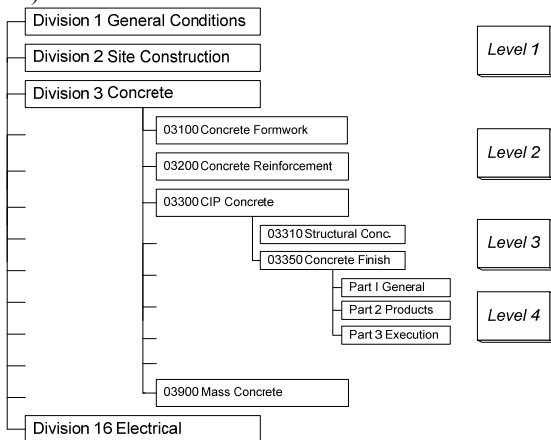
Division 1 General Conditions
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**Figure 1 Structure of Technical Specifications Based on CSI Masterformat™**

## 3. MOBILE DAILY REPORT SYSTEM

Technologies for mobile data collection are readily available. Without much modification, Pocket PCs, Palms and mobile telephones can be used to collect data by taking pictures and recording voices and notes. The key issue is how to organize collected data and utilize it to manage the project. The data collected through mobile devices have to be organized according to the industry standard for construction information.

The data that is collected and documented is related to progress of work at the job site. The amount of work performed and the labor and material spent for the work are two major types of information. Quality control, paperwork and drawing organization, cost management, and site weather conditions are important subjects of data management.

The formats of data that would be collected can be any of multimedia data; text, image, sound, and video. For example, quantity of materials and number of workers are in text form while work progress or assembly process can be in images and videos. Voice recording is also necessary when the jobsite circumstances prevent the user from taking notes.

### 3.1 Hardware Configuration

The hardware consists of a mobile unit (Pocket PC), a notebook PC, and a data/web server. The mobile unit is collects data at the jobsite. The PC unit is used to download the data from the mobile unit and upload to the web server. The web server contains the database and provides the web service. Figure 2 describes the hardware and network configurations for the mobile daily report system.
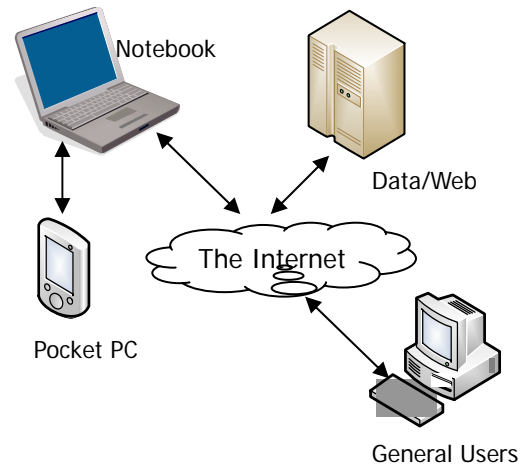
Notebook
Data/Web
The Internet
Pocket PC
General Users

**Figure 2 Hard Configuration of Mobile Daily Report System**

The mobile unit used in the development is a Dell X30 Pocket PC with a Veo® external camera which is inserted into the available SD memory card port. The software necessary for the system is automatically downloaded when the Pocket PC is connected to the server PC via a USB cable. No other modification or development was necessary to use this system for the purposes which made maintenance-free operation. Figure 3 shows the notebook PC, mobile unit (Pocket PC) and its attached camera.

**Figure 3 Hardware components**

## 3.2 Database Structure

The data structure for the system is designed to accommodate different data formats such as texts, numbers, and binary data (i.e. pictures and videos). A single report page which is equivalent to a one day's report can contain the information about the reporting person, date and time, weather, WBS (Work Breakdown Structure), and multiple pictures, sound recordings, and sketches. Figure 4 shows the database structure of the daily report system.
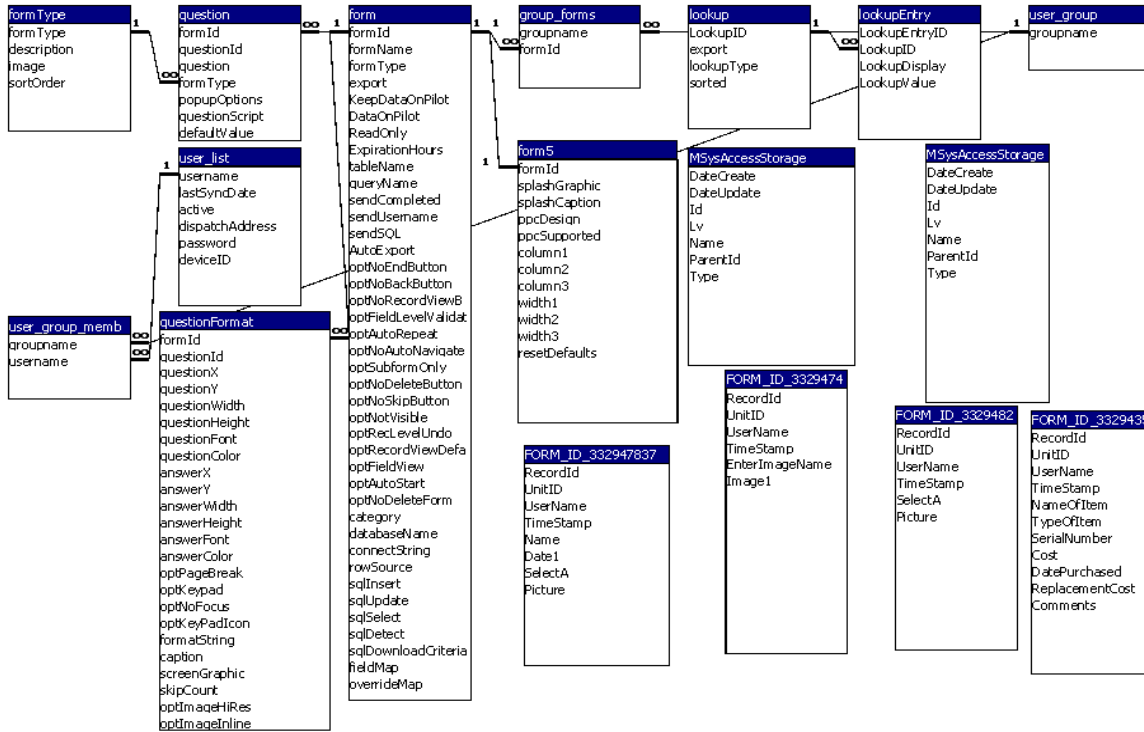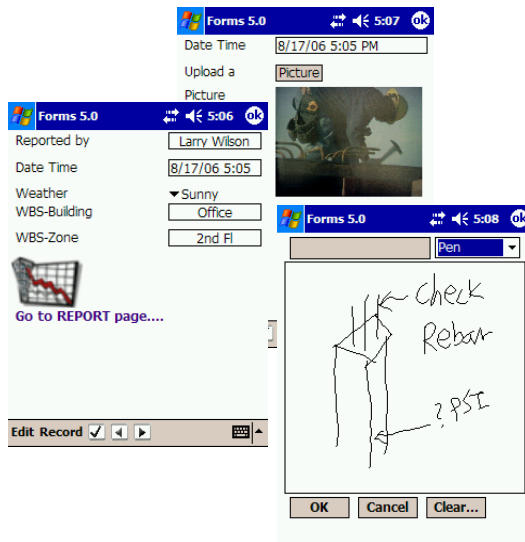
**Figure 4 Database Structure of Mobile Daily Report System**

## 3.3 User Input and Web Service

The user operates the mobile unit at the jobsite using a stylus on the touch panel.   Keyboard input is minimized for easier and quicker operation of the system.   Figure 5 presents some examples of user's data entry.
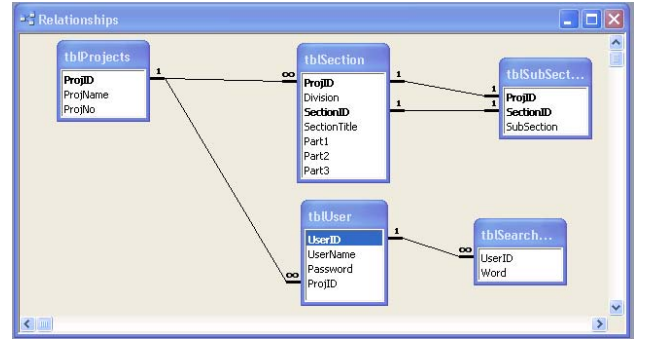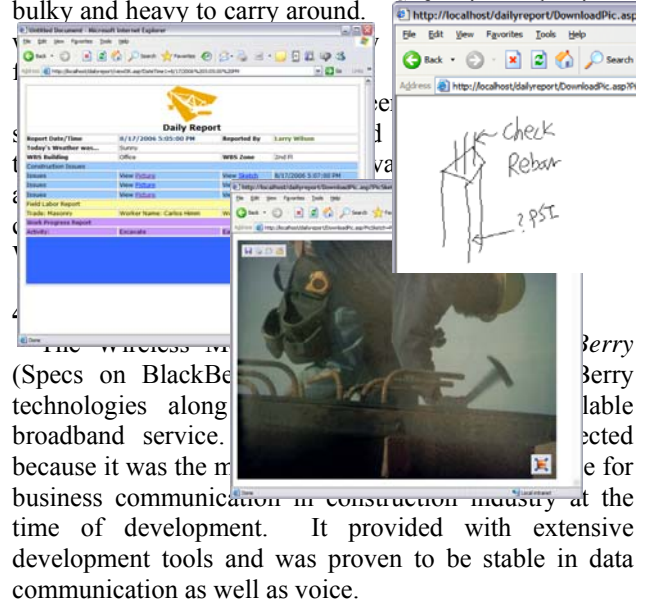
**Figure 5 User Input Examples**

The data entered by a user must be uploaded to the server to be available to other users.   When the mobile unit is connected to the notebook PC unit via a USB cable or wireless network, the newly entered data is automatically downloaded to the PC, and then uploaded to the server.   Once the day's report is uploaded, the collected data becomes available to other users as active web pages.   Figure 6 demonstrates web publication of the collected data.

**Figure 6 Collected Data Published As Web Pages**

## 4. MOBILE SPECIFICATION SYSTEM

To conform the work to the construction documents, project engineers need accesses to the construction documents right at the work is being done.   Many engineers carry a roll of drawings and booklets of specs for their review while in the jobsite.   This often creates problems because construction documents are usually bulky and heavy to carry around.

The Wireless M                           *Berry* (Specs on BlackBe                        Berry technologies along                      lable broadband service.                     ected because it was the m                    e for business communication in construction industry at the time of development.   It provided with extensive development tools and was proven to be stable in data communication as well as voice.

**Figure 7 Database Structure of Mobile Specification Systems**

To use the system, the user would select a project, a *Division* (Level 1), a *Section* (Level 2), a *Sub-section* (Level 3), and a *Part* (Level 4).   The data structure is developed in a way similar to the hierarchical structure of Masterformat™.

Figure 7 illustrates the database structure of mobile specification system.
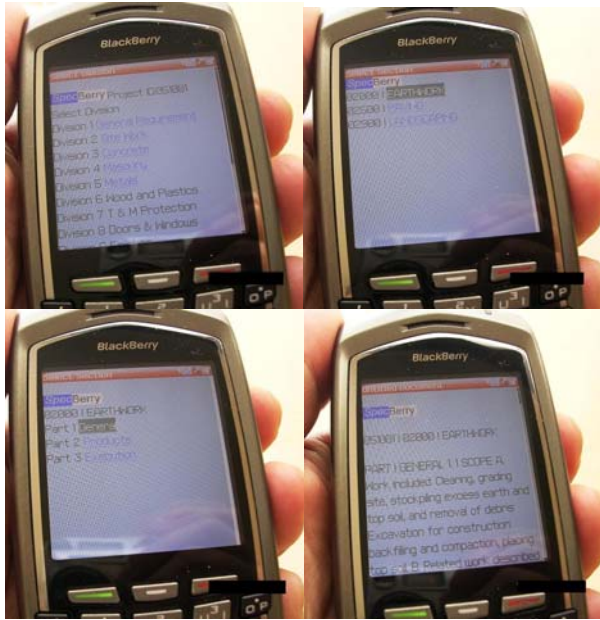
**Figure 8 Wireless Mobile System Screens**

Considering the unfavorable conditions of construction jobsites, user's keyboard input is minimized. The system is designed to operate with a scroll wheel and a button to navigate around the specs. The spec pages are brought to the device through the active wireless connection from the database, thus all the data can be accessed in real-time. Figure 8 demonstrates the operation of BlackBerry based wireless system. The user scrolls through Divisions, Sections, and Parts to display the contents of the specs.

### 4.2 Desktop Version

This version based on HTML (Hypertext Markup Language) is developed for desktop PCs and other web-capable devices such as PocketPC and some smart phones. It shares the same database of the wireless version. An additional layer of asp (active server page) written in Visual Basic Script (VB Script) transforms the data in the form of HTML so that the user can view the specs with various web browsers.

Additional functionalities are included such as advanced search and navigation. The user can search a specific word and find its related sections (i.e. look for a word '3000 PSI Concrete' and the sections that are related to '3000 PSI Concrete') so that all relevant works are examined. Figure 9 presents the screen view of the desktop version.
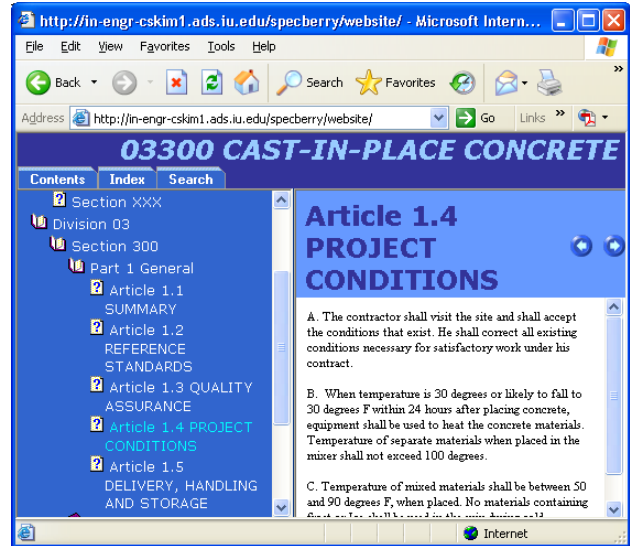


**Figure 9 Desktop Specification Access System**

### 4.3 Chip Version

The wireless and desktop versions will not be operable without network services. The chip version is developed for the projects where a broadband service is not available or when other situations prohibits the use of such services. It uses CHM (Compiled HTML) format for organizing specifications which is run on Windows operating system. The entire spec of the project is compiled into a single file and copied to a memory chip or to the hard disk of a mobile PC. This version shares the same database in the server but the user has to compile the data to be able to load into the chip.

CHM provides built-in indexing and search functions which enables the user' quick access to the spec sections. Figure 10 shows CHM formatted specifications and a chip in which the specifications are loaded.
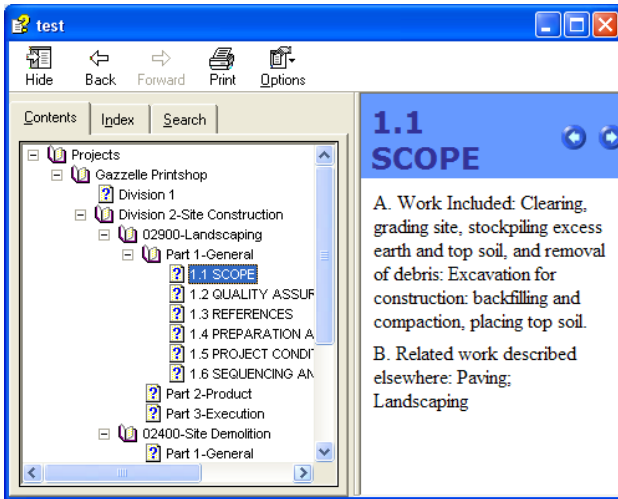
**Figure 10 CHM Format Specifications Loaded in a Chip**

## 5. CONCLUSIONS

This paper presented two cases of simple mobile applications for construction jobsite management. They are the examples which can be easily developed with commercially available software and without significant programming skills. The benefit of the systems is that they can be developed within a short time thus allowing instant responses to evolving needs and changes. Another benefit can be that they can closely meet the requirements because they can be developed by the user or the engineer who understands the requirements.

The development suggests that it is very important to establish a standard for collected field data in an alignment with the industry standard already in the works. This way, as data is collected, it can be seamlessly processed and become available to various project participants within or outside the organization.

An issue related to the hardware was the visibility of screen especially under bright sunlight. The quality of display has been greatly improved lately, thus visibility problems can be solved in the near future. The problems specifically related to the mobile specifications system was entering of data. Most construction specifications are in non-electronic form so that a large amount of effort was necessary to transform the specs to the proper database format.

## REFERENCES

[1] Aldunate, R., Ochoa, S., Peňa-Mora, F., and Nussbaum, M. "Robust Mobile Ad Hoc Space for Collaboration to Support Disaster Relief Efforts Involving Critical Physical Infrastructure." *Journal of Computing in Civil Engineering*, January/February, pp. 13-20, 2006.

[2] Chin, S., Kim, K., and Kim, Y. "Generate-Select-Check Based Daily Reporting System." *Journal of Computing in Civil Engineering*, American Society of Civil Engineers, October, pp. 412-425, 2005.

[3] Peňa-Mora, F. and Dwivedi, G. "Multiple Device Collaborative and Real Time Analysis System for Project Management in Civil Engineering." *Journal of Computing in Civil Engineering*, January, pp. 23-38, 2002.

[4] Reinhardt, J., Garrett, J., and Akinci, B. "Framework for Providing Customized Data Representations for Effective and Efficient Interaction with Mobile Computing Solutions on Construction Sites." *Journal of Computing in Civil Engineering*, April, pp. 109-118, 2005.

[5] Stumpf, A., Liu, L.Y., Kim, C.S., and Chin, S. "Delivery and test of the digital hardhat system at U.S. Army Corps of Engineers Fort Worth District Office." *USACERL ADP Rep. No. 99/6*, United States Army Corps of Engineers, Construction Engineering Research Laboratories, Champaign, Illinois, 1998