MOBILE CONSTRUCTION RFID-BASED SUPPLY CHAIN MANAGEMENT PORTAL SYSTEM

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ABSTRACT

The construction project control aims effectively to obtain real-time information and enhance dynamic control by utilizing information sharing connecting from involved participants of the projects to reduce construction conflicts and project delay. However, extending the construction project control system to job sites is not considered efficient since using notebooks in a harsh environment like a construction site is not particularly a conventional practice. Meanwhile, paper-based documents of site processes are ineffective and cannot get the quick respond to the office and project control center. Integrating promising information technologies such as radio frequency identification (RFID) technology and web portal can be extremely useful for improving the effectiveness and convenience of information flow in construction supply chain control systems. Radio frequency identification is appropriate for several construction applications, providing cost savings through increased speed and accuracy of data entry. This paper demonstrates the effectiveness of a RFID-based supply chain management application in construction projects, called the Mobile Construction RFID-based Supply Chain Management (M-RFIDSCM) System, that responds efficient ly and enhances the information flow between offices and sites in a construction supply chain environment. The advantage of the M-RFIDSCM system lies not only in improving the efficiency of work for on-site engineers, but also provide the kanban-like visual control system for project participants to control the whole project. Moreover, this paper presents a generic system architecture and its implementation.

KEY WORDS

Construction facility management; RFID; Mobile; Portal; PDA

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INTRODUCTION

The construction industry is extremely complex because total project development generally comprises several phases, thus requiring a diverse array of specialized services and the involvement of numerous participants. Therefore, controlling and managing construction projects effectively are extremely difficult owing to the involvement of various participants. Real time monitoring and control for the construction project may be necessary and helpful in completing projects comply with project budget and deadlines. With the advent of the Internet, web-based information management solutions enable information dissemination and information sharing among project participants. Generally, construction managers and on-site engineers require access to the construction site to manage a construction project since most such project are operated at construction sites. However, current desktops and notebooks are not suitable for using on construction sites because of problems in transportability. On-site engineers generally handle various types of digital information, including drawings, specification, checklists and daily reports. On-site engineers generally use sheets of paper and/or field notes. Consequently, a time and space gap exists between the construction site and the office, which reduces efficiency and creates a lack of data and data confusion.

PROBLEM STATEMENT

Project management and control performance can be enhanced by enabling participants to share information with each other. However, two major key aspects of information sharing are information acquisition and information communication. Information acquisition problems in a construction project follow from most of the data and information being gathered from the construction site, which is an extension of the construction chain. The effectiveness of information and data acquisition influences the information flow between the office and the construction site. However, on-site engineers generally use written documents, drawings, contracts, specifications and shop drawings for job sites. Consequently, a time and space gap between the job site and the office causes duplication of data and information, lack of data and information, and associated confusion. Restated, existing means of processing information and accumulating data are not only time-consuming and expensive, but also compromise project management performance in information acquisition. Such means of communicating information between sites and offices, and among all participants, are ineffective and inconvenient.

RESEARCH OBJECTIVES

This study designs a web portal to solve the information communication problem. This portal is controlled by a general contractor, and provides subcontractors and suppliers with real-time project-related information-sharing services, enabling them to dynamically respond to the entire construction supply chain network. This study develops Mobile Construction

RFID-based Dynamic Supply Chain Management (M-RFIDSCM) system to improve efficiency and cost-effectiveness of project control, improve practical communication among participants, and increase flexibility in terms of project delivery and response times. M-RFIDSCM system is a web-based system for effectively integrating general contractors, subcontractors and suppliers, to produce and distribute construction materials in the appropriate quantities, to the right locations and at the right times.

Documentation is increasingly superceded by integrating PDAs and RFID technology with the M-RFIDSCM system to provide easy access to information. PDAs can extend M-RFIDSCM systems to construction sites. Data collection efficiency can also be enhanced using RFID-enabled PDAs to enter and edit data on the job site. By using web technology and mobile devices, the M-RFIDSCM system for general contractors has tremendous potential to increase the efficiency and effectiveness of information flow, thus streamlining construction processes with other participants.

On-site engineers frequently waste time by traveling to obtain information in the absence of other efficient means of communication. The portal and PDAs enable on-site engineers to update data from the construction site and immediately upload it to the supply chain web portal; suppliers and subcontractors can receive real-time project-related information and make better decisions regarding future project management and control. The system assists project managers to make the right decisions in a "quick-response" environment.

This study develops a mobile supply chain control system for construction projects. The main purposes of this study include (1) developing a framework for a mobile supply chain control system for construction contractors; (2) applying such a system that integrates RFID technology with PDA technology to increase the efficiency of job site data collection; (3) designing a web-based portal for construction supply chain control, providing real-time information and wireless communication between offices and sites, subcontractors and suppliers; (4) providing on-site engineers with updated information, accessed via the internal supply chain control system between the office and job site, and (5) supporting project managers of each partner in monitoring and controlling the construction process dynamically. Figure 1 illustrates solutions used in a real example involving construction in a High-Tech factory building in Tainan by N-Wang Construction Corporation. With appropriate modifications, the M-RFIDSCM system can be utilized at any construction site for contractors or suppliers in support of the M-RFIDSCM system.

APPLYING RFID TO CONSTRUCTION

The use of technology to improve the delivery process control is not a novel concept. Barcodes have a long history of tracking materials not only in construction but also in other industries. By the beginning of the 1990s, construction firms began to examine the use of barcodes for tool management. Although an established and affordable technology, barcodes used in construction suffer the problems of having a short read range and durability: barcodes require a line of sight and become unreadable if they are scratched or dirty.

Similar to bar code application, Radio frequency identification (RFID) is an automatic identification solution that streamlines identification and data acquisition. In recent years automatic identification procedures have become very popular in many service industries, purchasing and distribution logistics, industry, manufacturing companies and material flow systems. In the construction industries, Jaselskis and Anderson (1995) studied construction applications and limitations of RFID technology in the construction industry include proximity of equipment, nearby metallic objects, costs, and workforce attitudes. Then, the application of RFID technology has been applied in many areas in the construction industries, such as in the following: (1) provide owners and contractors with information about enhancing their operation using radio frequency identification (RFID) technology (Jaselskis and Tarek, 2003); (2) propose new concept of "parts and packets unified architecture" to use RFID technology handling data or information related to a product carried by product itself in the unified controller system (J. Yagi et al., 2005) and (3) evaluate the use of RFID technology as a possible solution to some of these problems through automation of the current taking process and identify potential economic benefits from using RFID technology in automated tacking (J. Song et al., 2005).

RFID is the technology that uses radio waves to identify people and objects. An RFID system consists of an RFID tag and an RFID reader. The RFID tag consists of a small microchip and an antenna. Data is stored in the tag, usually in the form of a unique serial number. RFID tags can be either "passive" (no battery) or "active" (battery present). Active tags need a battery and are more expensive than passive tags and have a read range of several meters (10 to 100 meters). Passive tags don't need a battery and have a read range between 10 mm to about 5 meters (Manish and Shahram, 2005). The vast majority of RFID tags are passive in nature.

The RFID reader acts as a transmitter/receiver. The reader transmits an electromagnetic field that "wakes-up" the tag and provides the power required for the tag to operate (Manish and Shahram, 2005). The tag then transfers the data to the reader through the antenna. This data is then read by the RFID reader and transferred to the Pocket PC or computer. Unlike barcodes, RFID tags do not have to be line-of-sight. They only have to be within the reader's radio range. Also unlike barcodes, RFID tags can be read through most materials. RFID tags are getting smaller and smaller some are 1/3 of a millimeter across. RFID systems use many different frequencies, but generally the most common are low (around 125 KHz), high (13.56 MHz) and ultra-high frequency, or UHF (850-900 MHz).

RFID systems are one of the most anticipated technologies that will supposedly transform processes across the engineering and construction industries. Special in construction industries, RFID technology can be assisted with PDAs to enable on-site engineers to integrate seamlessly work processes at job sites, because of its accuracy and ability to capture data effectively. With a RFID scanner plugged into a PDA, the RFID-enabled PDA can be a powerful portable data collection tool. Additionally, RFID readings increase the accuracy and speed of information communication, indirectly enhancing performance and productivity. Figure 4 illustrates the application of RFID-enabled PDA using in construction projects.

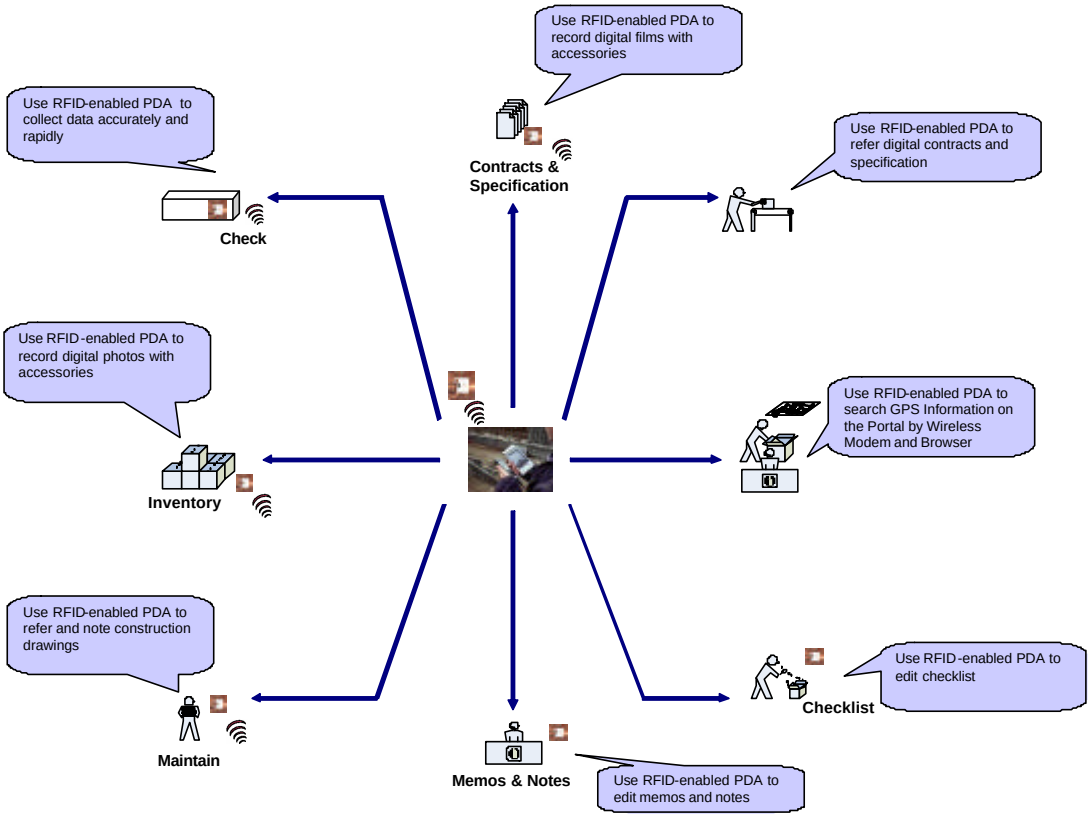

Figure 1: Average ± Standard Deviation of Buffer Size Relative to Number of Rolls after

APPLICATION OF RFID-ENABLED PDA USED IN CONSTRUCTION PROJECTS

Using PDA on Construction Sites

Various mobile devices have been adapted to field work on construction sites. Recently, the Personal Digital Assistant (PDA) revolution has affected the construction industry. The popularity of PDAs is growing rapidly as more powerful devices are developed and a wider range of applications become available. The key features of PDAs include: (1) calendar, address book, notes and to do lists; (2) browsing the Internet; (3) Internet access either via modem, cell phone or wireless access; (4) synchronizing data between PDAs and desktop PCs; and (5) platforms for add-on software (McPherson, 2000; Johnson and Broida, 2000).

The benefits of using mobile devices in the construction industry are well documented (Baldwin et al., 1994; Fayek et al., 1998; McCullough, 1997). Furthermore, the application of mobile devices has been applied in numerous areas in the construction industries, including the following: (1) providing wearable field inspection systems (Sunkpho and Garrett, 2003); (2) supporting pen-based computer data acquisition for recording construction surveys (Elzarka and Bell, 1997); (3) supporting collaborative and information sharing platforms

(Pena-Mora and Dwivedi, 2002), and (4) utilizing mobile computers to capture data for piling work (Ward et al., 2003).

Using a Portal in the Construction Supply Chain

Portals, a unique and sometimes complex concept introduced in the late 1990s, are web sites that collect information related to specific themes or topics and provide users with access to related services and information sources. Besides, a portal is an ideal platform for sharing information in a supply chain system. When a portal is used, all project-related information that is centralized in a project database can be obtained only via a web interface. The portal also provides authentication and access control mechanisms to allow project participants to access information based on user privileges and activity-related units. However, in practice the exchange of information among participants is more difficult than it seems. Several different systems and standards are used; the peer-to-peer relationships among companies in the network are normally too many to manage, and most systems do not support easy information exchange with other systems. Furthermore, most participants are extremely reluctant to share information with others. Portals represent a solution to these problems. Standardized interactions with a single portal are easier to manage than numerous peer-to-peer relationships. Electronically exchanging information reduces errors and increases work process efficiency. When individual participants can use the information of other participants in the supply chain, the negative effects of uncertainty are theoretically eliminated.

3. DEVELOPMENT OF the M-RFIDSCM SYSTEM

The internal construction supply chain management (ConSCM) system can be divided into three subsystems: the enterprise resource planning (ERP) system, the construction supply chain management Hub (ConSCMHub) system, and the mobile construction RFID-based dynamic Supply Chain Management (M-RFIDSCM) system. The M-RFIDSCM system extends the ConSCM system from offices to job sites to assist with forecasting and analysis services, while the ERP system primarily deals with data transactions in all departments or systems integration within a construction company.

All data are stored and classified using activity-based units in the M-RFIDSCM system. Additionally, the M-RFIDSCM services described in this study are made available to all project participants (suppliers and subcontractors) via a specially designed portal, which also serves as a real-time and mail communication channel for projects. All the authorized participants can run quality controls, schedule controls and inventory management, based on the data shared through the portal service. When the data are updated on the server side, e-mails are automatically sent from the server to the project manager of the general contractor, and to participants involved in the relevant activity. The following section outlines the development of the M-Con-RDSCM system in detail.

The M-RFIDSCM system comprises three components: - PDA, RFID and portal. Notably, both the PDA and the RFID components are on the client side, while the portal component is on the server side (see Fig. 5). Within the M-RFIDSCM system, all project-

related information acquired by on-site engineers is centralized in a supply chain system database (portal model database). Project participants (subcontractors and suppliers) in the supply chain may be able to access all or some of this information via the portal, depending on their access privileges.

The server of the M-RFIDSCM system comprises three distinct types of layers - namely presentation, application and database layers - each with their own responsibilities.

The presentation layer defines administration and end-user interfaces suitable for the work of that end-user. The users can access necessary information via web browsers, including Microsoft Internet Explorer or Netscape Navigator. Moreover, administrators can control and manage information through the web browser and a separate server interface.

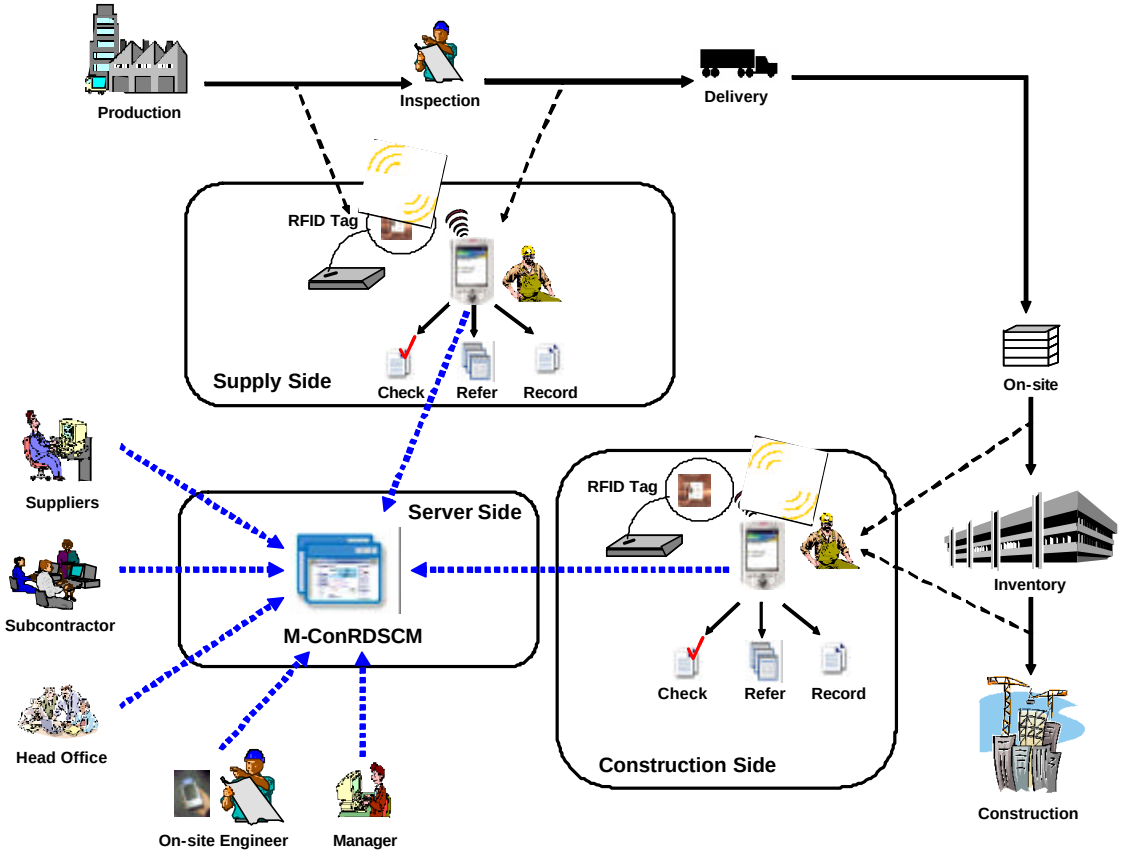

Figure 2: M-RFIDSCM System Framework Overview

Modules of the M-RFIDSCM System

The M-RFIDSCM system comprises a construction supply chain control portal integrated with mobile devices and RFID technology (RFID-enabled PDA). The following briefly describes each module.

The ConSCM portal is an information hub in the M-RFIDSCM system for general contractors. The ConSCM portal enables all the participants to log onto a single portal site and immediately obtain the information they need for their own planning. The portal is a simple presentation such as "Kanban" which is designed for both suppliers and subcontractors. The portal provides suppliers with information regarding the inventory levels of other portal users and enables them to manufacture products accordingly. The GC can access diverse information and services via a single front-end on the Internet. For example, a supplier can log onto the portal, enter an assigned security password, and access real-time production schedule information. The general contractor can check on order production or shipping status, the availability of inventory or various other project-related data.

The ConSCM portal is based on Microsoft's Windows 2000 operating system with Internet Information Server (IIS) as the web server. The prototype is developed using Java Server Pages (JSP), which are easily incorporated with HTML and JavaScript technologies, to transform an Internet browser into a user-friendly interface. Microsoft's SQLServer 2000 serves as the database for storing all information OR information storage. All e-specification and e-contracts saved in the server must be stored in e-book format for downloading into PDAs at the job-site. The ConSCM Portal provides a single personalized gateway that enables all engineers using the ConSCM system to access relevant information sent back from the PDAs. The ConSCM Portal provides a solution involving a single, unified database, linked to all functional systems with different levels of access to information, depending on the role of the user, both within an organization and across organizations and other supply chain participants.

Two mobile device platforms, Palm OS and Windows CE, are selected as the RFID-enabled PDA hardware systems. The M-RFIDSCM system uses Palm VII with Palm Reader 7 and Pocket PC with MPR-1230 RFID Reader. In the M-RFIDSCM system, RFID tags and tags are applied to the materials, equipment and property, as well as to the item control list. All construction RFID applications in the M-RFIDSCM system are capable of reading and writing to industry stantdard 125KHz or 13.56 MHz RFID tags ,and RFID tags are printed using high-quality laser printers.

RFID technology can be classified as either a passive or active system. The primary difference between active and passive RFID systems is that active tags contain an internal battery and can transmit the information to the reader without the additional electromagnetic field produced by the reader. In this study, passive tags are used as RFID tags because of the consideration of budget. Two RFID softwares are used in these systems, namely barcode-taging software and barcode-tracking. RFID-taging software is used for designing and printing quality tags, while RFID-tracking software is applied to RFID reading and tracking.

As mentioned in the previous section, the Palm OS and Windows CE are the two platforms used to operate the M-RFIDSCM system. Visual Basic and eMbedded Visual Tools 3.0 are the programming language and tools used for module development. IBM DB2

Everyplace and Universal Database are used as the PDA database for the Palm OS-based PDA; moreover, SQLServer for CE serves as the PDA database for the Windows CE-based PDA. Additionally, On-site Viewer (http://www.autodesk.com) for Windows CE is installed on the Windows CE-based PDA to allow viewing, marking up and measuring of AutoCAD drawings on the PDA.

All of the data files in the PDA module are first stored in the PDA database before being sent to the server through the Internet. Following the application is run in the PDA, all the data files are sent, transformed and saved in the server side database using Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC) technologies.

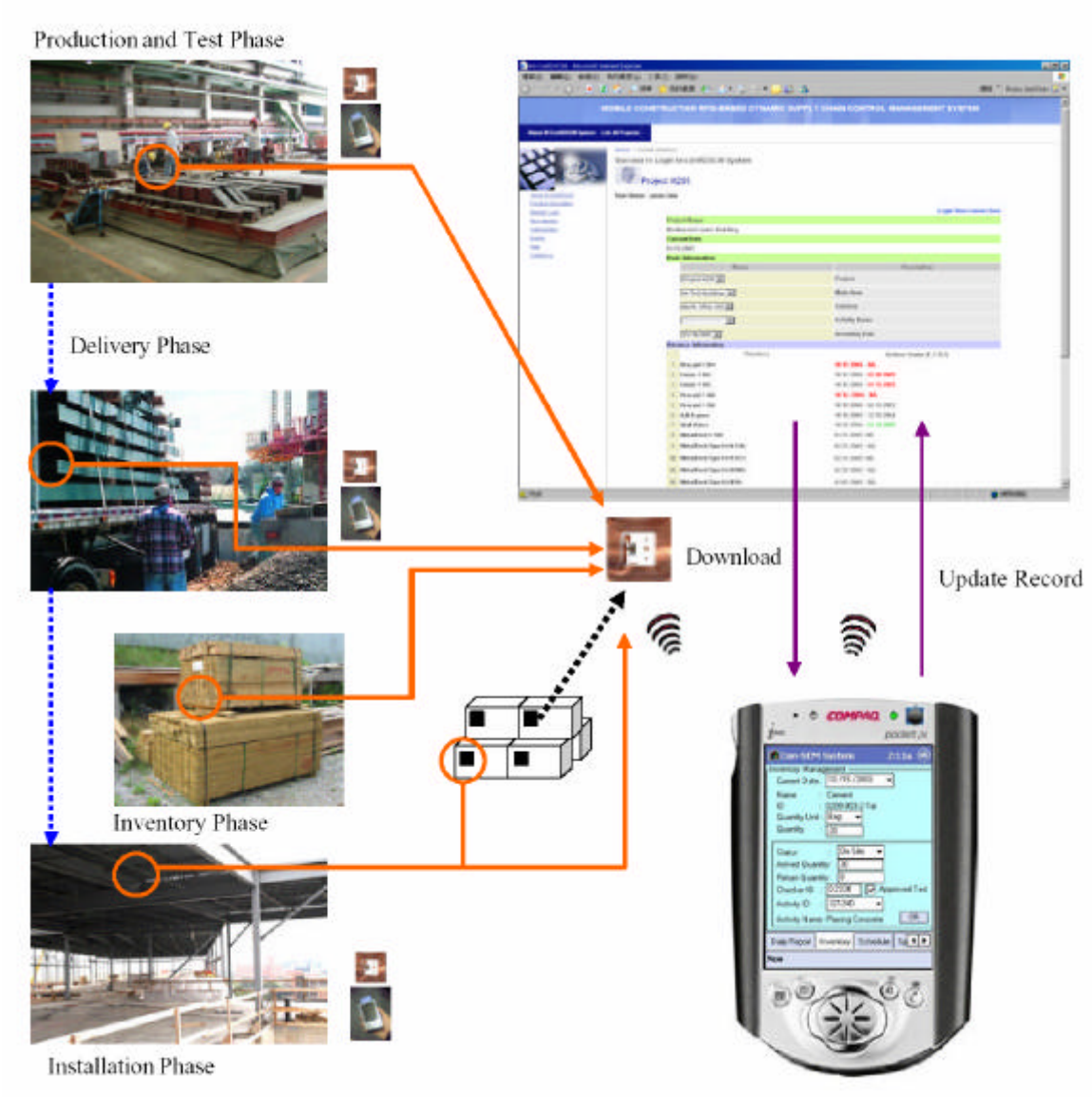

Fig. 11. The Application of PDAs Using in on-site Phase

CONCLUSIONS

This study presents a web-based portal system that incorporates wireless technology and mobile devices to improve the efficiency and effectiveness of on site data acquisition and information sharing among participants to assist managers in controlling and monitoring delivery progress in construction supply chains. The M-ConRDSCM system not only improves the acquisition of data on site efficiency using RFID-enabled PDA, but also provides a monitor to control the construction progress. On the client side, on-site engineers use RFID-enabled PDAs to overcome time and space constraints, enabling them to seamlessly integrate work processes at job sites, owing to its accuracy and ability to capture data effectively. Plugging a RFID scanner into a PDA creates a powerful portable data collection tool. Additionally, RFID readings increase the accuracy and speed of information communication, indirectly enhancing performance and productivity. Meanwhile, on the server side, the M-ConRDSCM system offers a hub center to provide suppliers and subcontractors with real-time updated project-related information and to monitor the construction progress. In a case study, the application of the M-ConRDSCM system helps to improve the monitoring of operation progress for High-Tech factory building, located in Tainan. As a process tracking technology, this study demonstrated that passive RFID technology has significant potential to enhance supply chain control and management in construction project. The integration of production and delivery real-time information from precast supplier helps the GC manager to monitor and control the whole construction progress. Furthermore, the precast supplier can update the erection progress in real time to reschedule the precast component production and assessment. Real-time feedback on the status of progress on site is provided to the fabricator off site so process steps can be re-sequenced as required. Compared with current methods, communication of information/data on the site can be enhanced by using RFID-enabled PDAs, and the information sharing among participants can be accelerated and made more efficient via the portal technology.

ACKNOWLEDGMENTS

The authors would like to acknowledge the National Science Council, Taiwan, for financially supporting this work under contract number NSC-2211-E-231-001 and express our appreciation to the Golden House Construction Inc for assistance in the system design and interviews, and to the experts and engineers of the owner of the project for providing useful data, valuable information, and helpful comments during system design and development.

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