INTEGRATING BAR CODING AND RFID TO AUTOMATE DATA COLLECTION FROM CONSTRUCTION SITES

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ABSTRACT

Tracking and control construction projects depends primarily on the nature, accuracy, frequency and time required to collect onsite data of construction operations. Automated data collection methods can improve the speed and accuracy of data acquisition in a cost effective manner. The bar coding technology, for example, was introduced in 1973 (Shepard 2005) to automate the process of data collection. At that time it was compared with manual data collection. Subsequently, other technologies emerged to enhance the speed of data acquisition and circumvent some of the limitations of bar coding. RFID works in a manner similar to that of bar coding (Jaselskis 2003), whereas in RFID data can be stored in tags and retrieved with readers that can communicate with the tags using radio frequency waves instead of light waves as in bar coding. Implementing RFID into the construction industry is tied with the cost associated with that technology. The ideal approach is to replace bar coding with RFID. This paper presents a data collection methodology that utilizes both RFID and bar coding technology to track project cost and schedule information. RFID components are described and its applications into different industries are highlighted. A comparison is also given between RFID and bar coding to highlight the advantages and limitations of each. This paper also identifies construction data needed for tracking and control processes and examines the best technology to be used to collect this data. Criteria like the cost associated with each technology such as the price of transponders and scanners and the use of active and passive RFID tags are taken into account. The proposed methodology is part of an undergoing research that integrates different data acquisition technologies to automate the process of data collection from construction sites, compare it to planned ones, and subsequently generate progress reports.

Keywords: Project control, RFID, Bar Coding, Data Collection, Construction

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INTRODUCTION

RFID was introduced to overcome some of the Barcode drawbacks, such as, 1) bar code reader must be very close to the label to be able to scan it, and must have line of sight which consumes man-hour, 2) limited amount of information stored in bar code tags, 3) information can not be changed once it's stored, and, most importantly, 4) bar code tags can easily be damaged or lost. The main advantage in applying RFID is that it doesn't have to have line of sight because it works with radio frequency waves. This may lead us to a question: would RFID replace bar code in the construction industry? Simply it's not possible to replace bar coding with RFID because of the cost associated with RFID technology. This paper represents a system that integrates both technologies for the purpose of data acquisition to track progress of construction projects. Both technologies are briefly presented and there advantages and limitations are highlighted. Their integration into one control system is presented, which is part of an ongoing research that integrates different automated data acquisition technologies for the purpose of tracking and control of construction projects. The type of data used is from the highway construction industry. This includes construction equipment used for excavation and paving activities, labor and material.

BARCODING

The bar-code technology is widely known in the manufacturing industry as a reliable tool for resource management (Abudayyeh 1996). Applying it in the construction industry is hampered by the rough conditions of site operations that may damage bar code tags (Abudayyeh 1996). The Construction Industry Institute (CII) funded a research project in 1988 to explore the potential applications of bar code technology in the construction industry. In that research, two categories of applications were identified. In the first category bar code tags are applied to material, equipment, and containers and /or paper work. In the second category, bar-coded menus are used for the purpose of improving the speed and accuracy of data entering into computer systems (Bell *et al*. 1988).

Barcode System Components and Application

Bar code systems are composed of bar code labels printed on paper and coded in a way to identify the product it represents. The *Universal Product Code* (UPC) is widely used as a product coding system. It was first adopted for the grocery industry and became the most widely used standard for product identification and today there are five versions of UPC (Shepard 2005). Other coding systems are available such as the *European Article Numbering* (EAN) system and the *Japanese Article Numbering* (OAN) system. There are two versions available of the EAN. The second component is the laser scanner, which is capable of reading information coded on the bar code label. Scanners are available in different types. There are hand held scanners, pen scanners (or wand scanners), wall- or table-mounted scanners that the barcode is passed under or beside, fixed position scanner (an industrial reader used to identify product during manufacture), and pda scanners (a personal digital assistant (PDA) with a built-in barcode reader). The last componenet is the printer to print bar code lables.
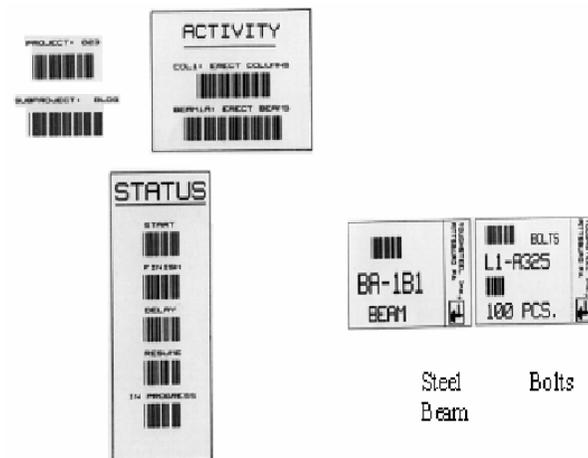
Figure 1 Bar code for an activity

During the control process, bar-code labels are scanned and data is entered into computer systems for later processing. Bar-code labels can be applied to material and equipment that are uniquely identifiable. Bulk material, such as gravel, can be stored in containers and issued a bar-code label. These labels are listed in menus to easily scan their tags (Abudayyeh 1991, Bell *et al*. 1988). Figure 1 is example of bar-code labels for an activity on an activity sheet and for a structural steel beam and bolts (Bell *et al*. 1988). For labor control, each worker is issued an ID card with his/her personal information and the information of the project he/she is working on (Flickinger 1995). Bar codes are either one-dimensional or two-dimensional. One-dimensional bar codes, unlike two-dimensional ones, can capture limited data and require the development of a relational database to support data retrieval and processing (Moselhi *et al*. 2003). One-dimensional bar codes were found to be more suitable to the construction industry due to the acceptance of standards governing one-dimensional codes, which can be adapted from other industries (Moselhi *et al*. 2003). Researchers have studied the potential of developing a data acquisition and storage model with the use of the bar-code technology and then processing this data for the purpose of integrating cost and schedule controls (Abudayyeh 1991).

RFID

RFID involves the use of miniature read/write transponders that are capable of storing data in harsh environment (Jaselskis *et al*. 1995). It works in a manner similar to bar coding, whereas in RFID data can be stored in tags and retrieved with readers that communicate with tags using radio frequency waves instead of light waves as in bar coding. RFID systems comprise tags, or transponders, and reader that include an antenna and a scanner. The tag contains a small circuit chip and an antenna that is encapsulated in a protective shell (Jaselskis 2003). There are two types of tags; active and passive. Active tags have a battery and more expensive than passive tags that can be charged from the reader. Tags can be read-only or read-write tags, and the read-write tags can be read-many write-once or read-many

write-many. The read-only tags are programmed only once (Jaselskis 2003). Examples of RFID tags and readers are shown in Figure 2 and Figure 3.
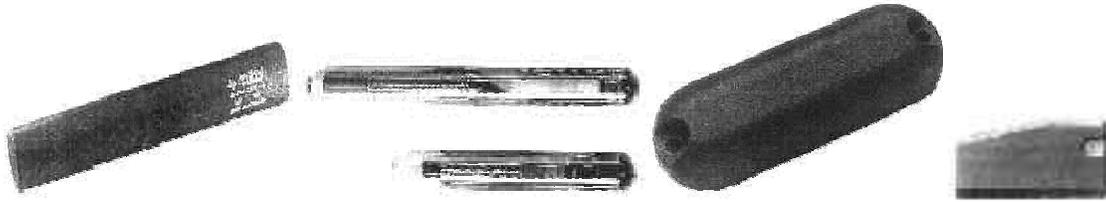
Figure 2 Examples of RFID tags (**www.rf-id.com**)

Figure 3 RFID Hand-held reader (www.rf-id.com)

COMPARISON BETWEEN BAR CODING AND RFID

As mentioned earlier the speed of data collection is crucial for the efficiency of the tracking process, hence, the application of RFID technology is to enhance the data collection process. We will introduce the differences between bar coding and RFID, their advantages and limitations so as to best utilize each technology for the intended purpose, vis-à-vis the accuracy and timeliness of the collected data. As observed in Table 1, the main differences can be summarized as follows:

- The scanning capablilties in case of RFID can be much faster and can also save more labor hours due to the fact that there is no need to approach the item in a very close distance to read its tag as in bar coding. In the construction industry this difrence would save time and cost when comparing the cost of implementing both technologies.

- The main disadvantage in bar coding is that tags can be easily damaged due to the harsh conditions of construction sites. This disadvantage can be overcome by applying RFID tages under such conditions.

- The cost of the labels is an important factor especialy on large projects when thousands of labels are needed. This is one of the main reasons why RFID can not entirely replace bar coding

- Changing infomation stored on tages might be needed. Working hourse stored on a worker's ID as well as his location, for example, can be changed as needed when using RFID systems.

Table 1 Comparison Between Bar Coding and RFID

	RFID	**Bar Coding**
Scanning	Doesn't require line of site	Requires line of sight
Labels	Can not be damaged	If damaged can not be read
Label price	20 cents and up	About 1 cent
Information	Can be changed on tags	Can not be changed

The cost of RFID depends primarily on the frequency used and on the type of tags, passive or active. Frequencies are divided into low, high, and ultra-high frequencies. Low frequency can be 124 KHz, 125 KHz, or 135 KHz and their range can vary from as low as few centimeters to 0.33 m. High frequency tags use 13.56 MHz and can read from up to 3.3 m. Ultra-high frequency use 860 to 960 MHz and read from a distance that ranges from 3.3 to 100 m (Roberti, 2005).

BAR CODING AND RFID FOR CONSTRUCTION AUTOMATED DATA ACQUISITION

The current research attempts to integrate different automated data acquisition technologies to collect data on construction sites and store it in a central database, which is then used to generate progress reports. Pen-based computers' technology is used as a media of integration. This system integrates RFID, bar coding, LADAR (Laser Distance and Ranging) and multimedia technology to automate data acquisition. The data needed for integrated cost and schedule control must be identified, organized and stored in a relational database management system. Data stored in that model include project activities, which have a cost account code to facilitate their retrieval. Each activity has a bar code listed in a menu. When starting the data collection process for an activity, the activity is called by scanning its bar code so that it appears on the pen-based computer screen. The activity can also be called by opening a scroll bar where all activities are listed. Information regarding resource

consumption are acquired and entered by scanning the tags associated with these resources and data related to the quantity or hour usage are directly entered. Each worker has an ID card when scanned, data pertinent to his working hours and the activity he is working on is entered. At the end of each working day, work progress data is collected. All activities have cost account codes to easily relate data to these activities. The data is augmented with digital photographs and video scenes, along with any other comments written directly on the screen or recorded via a microphone hooked to the pen-based computer (Moselhi *et al*. 2005). The process of data exchange is highlighted in Figure 4 where planned data files are imported from the scheduling software Primavera (the system used for scheduling in the proposed model) to the data acquisition module and after modifying those data files, they will be sent back to Primavera for updating the schedule. Table 2 maps the integration of different automated data acquisition technologies designed to collect data from construction sites.
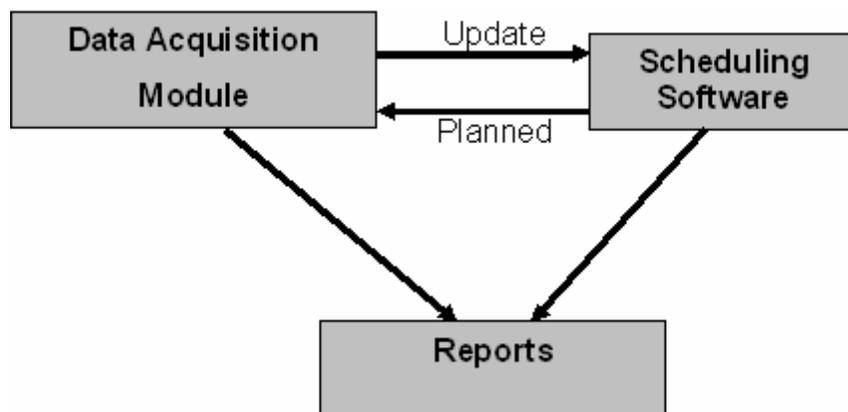

Figure 4 Data Exchange and Reporting

CONSTRUCTION DATA COLLECTION (HIGHWAY CONSTRUCTION)

Highway construction project data include equipments for earthwork operations and for pavement operations, as well as material and labor for these main operations. RFID is utilized for material transported to the site such as asphalt. Trucks are provided with RFID transponders to record information on the material being transported. This, for example, can be the temperature of asphalt being transported to the job site. Equipment used on site can be provided with bar code tags, when scanned information are entered related to their start and finish time together with the section the equipment is working on. Workers are provided with RFID ID cards to track their location on site as needed. Applying passive or active tags depends on the item that it is attached to. If the item information as in the case of asphalt needs to be changed then a passive tag must be used. The application of low, high, or ultra-high frequencies depends on the size of the project and also on its conditions. RFID or bar code readers are attached to the pen-based computer to scan items or workers' IDs and update data such as working hours and material quantities used. RFID scanners can be also fixed in different locations of the project site to scan the items while it passes through them. This system can also work in building and industrial projects. In that case, the application of bar code and RFID must be carefully studied due to the large numbers of tags needed.

CONCLUSION

This paper introduced the application of bar coding and RFID for tracking and control of construction projects. It first presented each technology and highlighted their advantages and limitations. The integration of both technologies was then presented as part of an ongoing research that integrates different automated data acquisition technologies for the purpose of tracking and controlling construction activities.

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Table 2 Construction Data Acquisition with Different Technologies

	Bar Code / RFID	LADAR	Pen-Based Computer	Multimedia		
				Photo Images	Video Images	Sound Records
Labor	1		1			
Material	1		1			
Equipment	1		1			
Quantity		1	1			
Task progress		1	1	1	1	1
Weather conditions			1			1
Productivity		1	1	1	1	1
Problem areas		1	1	1	1	1

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