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Survey and Analysis of Automated Civil Construction Material Tracking

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ABSTRACT

Materials management is a critical factor in construction project performance, particularly in the industrial sector. Research has shown that construction materials and installed equipment may constitute more than 50% of the total cost for a typical industrial project. Therefore the proper management of this single largest component can improve the productivity and cost efficiency of a project and help ensure its timely completion. One of the major problems associated with construction materials management is tracking materials in the supply chain and tracking their locations at job sites. Identification is integral to this process. Research projects conducted during the last decade to automate the identification and tracking of materials have concluded that such automation can increase productivity and cost efficiency as well as improve schedule performance, reduce the number of lost items, improve route and site optimization, and improve data entry. However, these technologies have been rapidly evolving, and knowledge concerning their implementation is sparse. One new approach enables locating of components within a few meters at a cost at least a magnitude lower than preceding technologies. It works by combining GPS located reads of RFID tags read at a rate of several thousand Hertz in order to estimate the location of these inexpensive tags which are attached to key construction materials.

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Background

The Construction Industry Institute (CII) (CII 1986) has defined materials management as “the planning and controlling of all necessary efforts to insure that the correct quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available when needed.” Materials management is a system, not the organization responsible for performing these tasks (The Business Roundtable 1982). Construction materials management has also been recognized to include the integrated coordination of materials takeoff, purchasing, expediting, receiving, warehousing and distribution (Bell and Stukhart 1986). It is an indispensable part of the project management which can be integrated with engineering to provide an end product that meets the client’s requirements and is cost effective (Kini 1999). Materials management extends beyond inventory management. It involves: the procurement of equipment and materials, inspection and delivery to the job site, inventory control and the disposal of surplus material at the time of project completion (Silver 1988). Figure 1.1 shows the organization chart for a typical engineer/procure/construct (EPC) project.

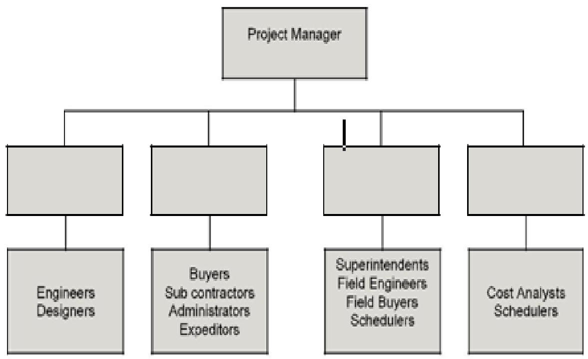

Figure 1.1: Organization chart for EPC project (Based on Kini 1999)

Research Objectives:

The main objective of this semiar is to develop a model for automated tracking and locating of construction materials and equipment for increasing productivity and cost effectiveness. The model is focused on large and complex projects such as industrial, infrastructure, and large scale commercial. The scope of the research is further focused on the system architecture and management elements of the automated materials tracking system,not on the underlying aspects of the technology which is described in other publications (Song et al. 2005; Caron et al. 2006; Song et al. 2007; Caron et al. 2007). Pursuing the following sub-objectives helped in achieving the main objective of the research:

1.Study the existing and emerging techniques of automated materials tracking systems and discuss their limitations.

2.Describe and develop morphologies of these systems.

3.Develop principles, methods and knowledge based on analysis of two large scale field trials to help develop processes for implementation of automated materials tracking systems on future projects.

4.Identify and discuss integration issues with project information technology systems and materials management processes.

5.Explore integration issues of automated materials tracking with the supply chain management process of the construction industry.

Consider the impact on lean construction ideas, the just-in-time delivery concept, and reduction of multiple material moves

Research Methodology:

To achieve the above research objectives in the context of two large evolving field trials, an iterative progression through the following steps was followed:

1.Comprehensively review the existing literature on materials management and automated materials tracking and locating.

2.Conduct field trials on two large industrial projects, on one of which the author was present for a significant amount of time.

3.Define the various terms, technologies, and deployment architectures involved in materials management, and automated materials tracking and locating.

4.Define the processes and functions for materials tracking such as receiving, invoicing, requesting (informing), locating, issuing and organizing space, etc.

5.Analyze the different available automated materials tracking technologies in terms of their suitability for materials tracking under different circumstances.

6.Synthesize and analyze the field trials data and the literature review.

7.Develop an implementation process for automated materials tracking for key materials and for large construction projects, based on preceding synsemiar and analysis.

Construction Materials: Stukhart (1995) defined material as “a substance or combination of substances forming components, parts, pieces, and equipment items.” Construction of a facility is a process where materials and equipment are being installed by craft workers according to designs and specifications (Tommelein 1998). Materials and installed equipment for construction projects have been divided into three categories (Halpin et al. 1987):1) Off-the-shelf,2) long-lead bulks, and 3) engineered items. The different categories of materials and installed equipment vary in cost, delivery lead time, and interchangeability.

The Construction Industry Institute (CII 1999) has classified three broad categories of materials, each of which require different approaches to their management and control. These categories are: 1) Engineered materials, 2) Bulk materials, and 3) Prefabricated materials.

2.2.1 Engineered materials: These are the items of the materials which have a uniquely assigned number (or tag) so that they can be uniquely referred to and identified throughout the entire life of the facility. They have been further divided into:

Major Equipment: These are the items which are engineered and fabricated specially for the project (e.g., tanks, heat exchangers, pumps, major instrumentation

Minor Equipment: These are the items that are manufactured to an industry specification and are often stocked by the manufacturer or the distributor. They are also uniquely tagged for identification purposes (e.g., minor instrumentation items, thermo wells, transmitters, specialty items).Engineered materials are the most visible, costly, complex and quality critical. These are identified and ordered by the engineering staff of the owner; they usually direct the project schedule; and the lead times of major equipment influence the entire schedule.

Bulk materials: These are items of materials which are manufactured to industry codes/standards, and are purchased in quantity. They do not have uniquely assigned identification numbers. These materials include items such as pipe, fittings, conduits, and cable. They are more difficult in terms of planning as they are many in numbers, and quantities are never exactly known until the job is done. Design changes cause continual updating of the bulk materials requirements (Stukhart 1995).

Prefabricated materials: These are the items that are typically engineered and fabricated in compliance with engineering specifications at a fabrication shop or site which is separated from the construction site. Depending on the project strategies, the component materials which constitute the fabricated items may be quantified, procured and delivered to the fabricator by the engineer or constructor. These materials include modules and preassemblies (e.g., ladders/platforms, structural steel, pipe spools, large and small process modules, and control stations).Each category of materials requires a different approach during the planning and execution stages of the project. Generally, engineered items are available at higher costs in smaller quantities and with more unique properties than long-lead bulk materials and off-the-shelf items, thus implying longer lead time and requiring more front end planning (Tommelein 1998).

Automated Data Collection (ADC) Technologies in Construction: In this section, the use of ADC technologies in construction is described. This description becomes important for understanding the architectures, field trials, and model developed in the following chapters. The use of ADC technologies in materials management, tracking, identification, and control are discussed. Automatic identification or Auto ID is a general term used to describe a range of technologies that are used to identify objects through the use of machines. Automatic identification is often used together with Automatic Data Collection (ADC). These Auto ID and ADC technologies are used to identify items, capture information about them and than transfer the data into a computer without manually typing it. The main aim of the ADC technologies is to increase efficiency, reduce data entry errors caused by human transcription, and reduce labor costs. There are a number of technologies that come under the Auto ID or ADC technologies. These include bar codes, smart cards, voice recognition, optical character recognition (OCR), radio frequency identification (RFID), and global positioning systems (GPS). While some have been implemented in their most basic form, they are rapidly evolving and beginning to be combined in innovative new forms. In the next sections, those technologies which have the potential to be used in the construction industry and particularly in materials identification, tracking, and locating are discussed in detail. Two decades ago, Bell and McCullouch (1988) suggested bar code applications in the construction industry. Their research, supported by the Construction Industry Institute (CII), aimed at the exploration of potential applications of the bar code technology and the associated cost-savings benefits of using bar codes in the construction industry. They also studied and recommended guidelines for the extensive use of bar codes in the construction industry and suggested industry-wide standards that are required for the implementation of bar codes. Their research studied the specific applications in the areas of quantity takeoff, field material control, warehouse inventory and maintenance, tool and consumable materials issue, timekeeping and cost engineering, purchasing and accounting, and document control and office operations. Their research also confirmed that bar codes use can improve the speed and accuracy of computer data entry and produce the same cost savings in the construction industry as seen in other industries. Rasdorf and Herbert (1990) provided an introduction to automated identification systems with particular emphasis on the bar coding technology. They explained the automated identification system criteria used to rate the system performance. They identified read rate, substitution errors, durability, and weather resistance as the criteria of identification system performance. They explained and compared the automated data collection (ADC) technologies in terms of their systems performance in the construction industry. They explained and compared the technologies which included; bar codes, optical character recognition (OCR), magnetic stripe (MS), and radio frequency (RF). They identified the potential use of bar codes in the construction industry for: 1) job site material management; 2) project activities; 3) document control, purchase orders, requisitions and drawings; and 4) construction equipment management. Their research stated that the automated identification system technology for data collection can provide better information flow to all the levels of management. Therefore the management can make better informed decisions which have a positive effect on the project performance. Bernold (1990) introduced a prototype system for tracking construction equipment and materials using a bar code driven technology. The aim of the research was to improve the accuracy and timeliness of the tracking information/data. The research was divided into two steps: 1) development and implementation of an automated tracking system and 2) checking the performance of bar code labels and adhesives in the construction environment. His research demonstrated how yard control systems could adapt the automated data collection technology of bar codes and utilize the advantages of the new system. The research also pointed out some of the important factors for the selection of labels and adhesives for use in the construction industry/environment. Jaselskis et al. (1995) provided information on radio frequency identification (RFID) and its potential applications in the construction industry. They discussed the use of three applications of RFID technology in the construction industry; 1) concrete processing and handling, 2) cost coding for labor and equipment, and 3) materials control. They concluded that construction firms could potentially save time, money, and effort with the effective use of RFID technology for several operational procedures. However, RFID technology had not matured enough at the time of the study to be used in the field. One problem was that the read-rate was too poor for field deployment. Navon and Berkovich (2005) developed a model based on automatic, or semi-automatic, data collection for materials management and control. Their proposed model would automatically generate and manage the ordering of the materials, based on the project plans. It would also monitor the actual flow of materials and report the status of materials on the construction site, would give warning when the specifications of the materials arriving at the site differs from those in the purchase order, and inform when the stock on the site is less than the desired minimum. The model was evaluated by comparing the existing/customary materials management and control procedures with that using the model. No field validation was done. Song et al. (2006a) presented an approach to automatically identify and track materials on construction sites without adding any extra site operations. They tagged the materials with RFID technology. Their approach leveraged the automatic reading of tagged materials by field supervisors or materials handling equipment that were equipped with an RFID reader and a global positioning system (GPS) receiver. A mathematical model was developed to check the feasibility of their approach by representing the job site as a grid, and the location of the materials within the grid were determined by combining proximity reads from a discrete range. The results of their field experiments conducted using an off-the shelf RFID system showed that the approximate 2D locations of materials can be determined without much cost using the proximity localization techniques.Their research findings of the automated tracking of the materials on the construction job sites demonstrated the potential for improvement of field materials management and for effortless derivation of project performance indicators for real time control of project management. Song et al. (2006b) demonstrated the use of RFID technology to track uniquely identified materials through the supply chain as well. They conducted field tests of the current RFID technology for determining its technical feasibility for automatic identification and tracking of individual pipe spools in lay down yards in industrial projects. Through their field tests they determined that the RFID technology can function effectively on construction sites that may involve large metal objects and that require a considerably long read range. They also proved statistically that the then commercially available active RFID technology can automatically identify pipe spools with 100% accuracy and precision when they are moved / passed through portal gates equipped with four antennas at a slow speed of less than 2 mph. Their study also suggested the potential benefits of using the RFID technology in automated tracking of pipe spools, such as: 1) less time required to identify and locate pipe spools, 2) accurate and timely information for both materials availability and craft work planning, 3) reduced search time for misplaced pipes and potential improvement on the pipe fitting schedule.

Conclusions:

The automated materials tracking system was found feasible and can be successfully applied on future construction projects.

The integrated, automated materials tracking system consisting of active RFID tags, reader, GPS and handheld PC was able to collect data about the materials with reasonable accuracy, identify and track materials, and locate materials in the supply chain.

The automated system can be integrated with the project information technology systems and materials management processes. A commercial firm has begun this process.

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