Materials Tracking Technology and Construction Applications

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Abstract

The costs arising from inefficient materials management systems can cost Engineering Procurement and Construction Management (EPCM) companies many thousands of dollars in large scale construction projects, such as Alcoa's Pinjarra Efficiency Upgrade (PEU). Time spent searching for assets when needed are not only inconvenient but may cause costly delays, eating into productivity and bottom line profitability. This project aims to investigate methods to improve the tracking of structural steel work at industrial construction sites. The project work can be divided into two phases. Firstly, the requirements definition stage entails a review of existing materials handling processes for the PEU project and compiling a list of project requirements. Secondly, the implementation stage involves identifying prospective tracking technologies and processes, researching how these can be implemented and performing a cost benefit analysis. The preliminary finding is that bar code technology is the most suitable tracking method for this application, as there are at present technical and practical limitations which need to be addressed before Radio Frequency Identification (RFID) can be employed.

1.0 Introduction

This project was instigated by Hatch Associates who are interested in what RFID could do to improve their materials management system. The aim of this project is to determine how effectively materials tracking technologies can be implemented to track steel work within the perimeter of the construction site. Successful implementation will facilitate savings on scheduling, rework, labour and material costs, help with dispute resolutions and promote a continuous uninterrupted workflow. This will lead to productivity improvements and improved bottom line profitability. The operations and materials management processes at the PEU project will be used as a guide to how typical EPCM companies operate and manage their materials. The PEU project is managed by Alcoa and Hatch Associates and has an expected mechanical completion date of the end of 2005.

2.0 Problem Definition

The aim of the site visit to Pinjarra early in the project was to observe how construction materials were managed and to get a thorough understanding of industrial construction sites in general. Forms of identification used on steel work included handwritten painted markings, hard stamping every member with a unique identification number and attachment of bar code labels.

2.1 Manual Data Collection Method

The manual approach is used to inventory and locate structural steel items. Structural steel is stored in the construction yard in priority groups and they are manually located when required. This is not a very efficient process especially for locating small items. Time spent searching for assets are not

only inconvenient but can also hold up construction work and result in costly scheduling delays. The whole process from identifying materials using labels, reading labels, manually recording material data and then transferring this information onto the computer system is very time consuming, which means that information used to monitor materials may be inaccurate or outdated. An inherent problem with the manual data collection process is that it is prone to human error.

2.2 Current Bar Code Method

Bar code technology is available for use but is rarely used as there have been difficulties with the technology. The major issue is that standard bar code labels are easily spoiled by the harsh environment inherent at an industrial construction site, including sun, wind, rain and radiating heat dirt, mud and corrosives, particularly as materials are often stored in the yards for months before use. Sticker labels are easily damaged during transport. Damaged and spoiled labels can render the traditional, sensitive bar coding technology useless.

3.0 Requirements

3.1 Environmental Factors

Tags, labels or any other form of the identification must be able to withstand the weather conditions and harsh environmental conditions inherent at an industrial site as well as have resistance to abrasion due to contact with steel, during transport to site in particular. The enormity of steel work including building structures can potentially affect any type of wireless application and devices need to exhibit good electromagnetic interference performance due to the level of electrical cabling and other electrical devices present on site.

3.2 Technical Issues

The reading device must be able to get a repeatable and reliable signal. This will determine the distance range from the steel work that the reader has to be within. The ability of the reading device to identify steel in the storage groups on site must be considered since the tags or labels may be in such a configuration that may make it challenging to communicate with.

3.3 Information Management

The monitoring system needs to capture and maintain selected data regarding the specific piece of steel or equipment. The reading device must be able to upload and synchronise its data with the office database system. The software maintaining this database needs to allow the importation of material data from another database. This would allow monitored materials to have their information pre-loaded into the database and then downloaded to the reading device prior to field inspections or locations being carried out.

3.4 Product Supply and Implementation Costs

The costs of implementing a proposed solution versus the benefits must be feasible. They include the costs of components, associated accessories, associated software, maintenance and any education or training requirements. The tags or labels need to be supplied in a timely and workable manner, and replacements must be readily available to avoid project delays.

4.0 Prospective Technologies

4.1 Bar Code Technology

A basic bar coding system comprises of: a label that is encoded with data and human readable information; a scanner that captures the encoded data and decodes it into machine readable signals;

and an external database that matches up the item's unique bar code with relatable information from itself or an associated database.

4.1.1 Benefits

Improved data accuracy is the key motivation for adopting bar code technology and this is critical to generating accurate reports and for decision making. Bar coding and other AIDC systems promote: labour cost reductions; improved customer service; improved supplier response time; better capital, inventory management and space management; and reduced materials and equipment costs (ZIH Corp. 2005). Conventional bar codes are restricted in that they can only store a small amount of data but this has been rectified with the development of the more capable 2D bar codes.

4.1.2 Limitations

A technical limitation inherent with any optical technology is that it requires line-of-sight to be read successfully. Bar code technology requires each item to be scanned individually and this translates to manual labour requirements plus the added possibility of human errors. A major limitation with traditional bar code label usage is that it is susceptible to damage while en route as well as in harsh environments, such as outdoors, around chemicals, moisture and high temperatures (d'Hont 2004).

4.2 RFID Technology

RFID technology is a form of automatic identification technology which enables "wireless communication between readers and tags with non line-of-site readability" (Schneider 2003). A basic RFID system comprises of a tag that is programmable and used for storing item data; an antenna that is the medium for reading and writing information in the tag; and a reader that processes the information in the tag. Tags can be read-only or read/write; can operate on a number of frequencies and are classified as passive or active depending on the way in which the tags receive power for transmission.

4.2.1 Benefits

RFID technology can eliminate delays and errors of manual data collection; can automatically identify locations and tracks assets; doesn't require line-of-sight to read tags; is flexible due to its multiple read/write capabilities; and rugged tags can be applied confidently in more extreme environments without loss of information data (SAT Corporation 2001).

4.2.2 Limitations

RFID can be read through virtually any material except metal, which blocks and cancels signals. RFID technology, particularly active systems are more costly than bar code systems.

5.0 Proposed Solutions

This section looks at how bar code and RFID systems can be deployed across the entire tracking process, from fabrication to installation, and whether or not they can satisfy the requirements.

5.1 Bar Code System

Multiple thermal transfer or metal bar code labels would be attached to every piece of steel and each item is to be individually scanned. Site workers would possess handheld mobile computers with integrated bar code scanners to scan labels at receiving and when locating required steel work for use. Useful data associated with any particular item can be retrieved from the central materials database onto the mobile computers. This information can then be viewed and edited at any time, and then transmitted back to the database to update records.

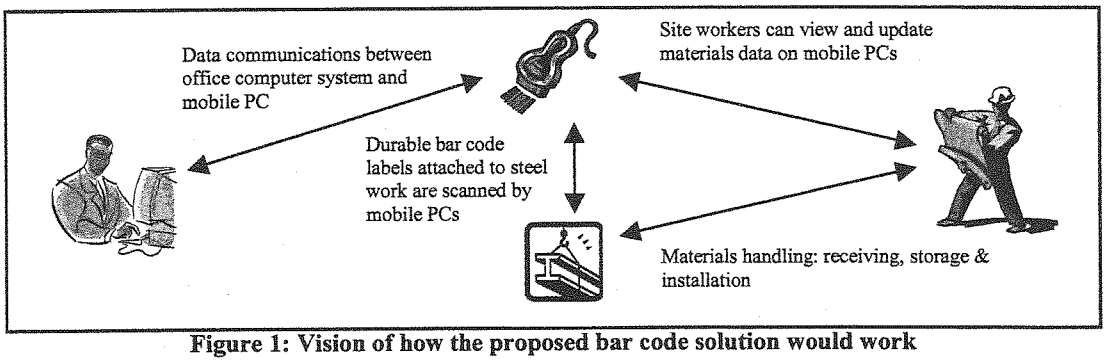

Figure 1: Vision of how the proposed bar code solution would work

5.1.1 Components

The two options for bar code labels are presented in the table below:

	Labels	Supply method	Scanners	Accessories	External database	Software
1	Resin formulated thermal transfer ribbon on synthetic substrates	Thermal transfer printers installed at supplier's premises	Handheld mobile computer with integrated bar code scanner	Docking stations	Existing or custom designed materials management systems	Bar code printing software
2	Metal labels made of aluminium with pressure sensitive adhesive	On site label marking using laser marking device	Handheld mobile computer with integrated bar code scanner	Docking stations	Existing or custom designed materials management systems	Laser marking software

Table 1: Proposed bar code solution components

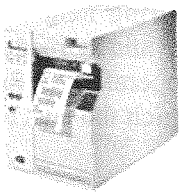

Figure 2: Thermal transfer printer by Zebra Technologies

Figure 3: Handheld mobile computer by Symbol

Figure 4: Metal bar codes for industrial use by Camcode

5.1.2 Cost/Benefit Analysis

Minimal training is required and the transition to an improved bar code system would be relatively easy to implement. The mobile computers allows for the potential for site workers to have access to any information wherever they may be. The major concern with using bar codes is the ability of the labels themselves to resist abrasion and the harsh environment. The inexpensive resin formulated thermal transfer labels may not stand up to the conditions and can be substituted for the metal labels built for industrial use. The option to use 2D bar codes can not only encode more data but they can be designed to have built in redundancy, which enables the labels to be read even if they are partially damaged or covered in dirt. Anticipated areas of improvement from implementing a new bar code system include: transportation, receiving on site, search and retrieval, and installation.

5.1.3 Cost Estimates and Estimated Savings From Implementation

Cost of Implementation

* Based on an estimate of 60,000 labels required (30,000 items @ 2 labels per item). ** All prices are based on quotes or estimates obtained from suppliers and all quantities are based on estimates of quantities required. *** Exchange rate applied: A$/ US$ = 0.7707 (13 September 2005)

Description	Qty	Unit Price**	Total Cost
Handheld mobile computers	10	$3,000.00	**$30,000.00**

Accessories (docking equipment)	4	$500.00	**$2,000.00**
			$32,000.00
1. Thermal transfer labels			
Fixed costs:			
Industrial thermal transfer printer	3	$2,799.00	$8,397.00
Label printing software	1	$660.00	$660.00
Setup & training of system	3	$195.00	$585.00
			$9,642.00
Variable costs:			
Wax Resin Ribbon	20*	$39.00	$780.00
White Paper Label Rolls	60*	$42.00	$2,520.00
			$3,300.00
			$12,942.00
2. Metal bar code labels			
Fixed costs:			
Laser system incl. printer, cartridges, software	3	$12,975.22	**$38,925.00**
Variable costs:			
Alloy aluminium label sheets	3000*	$31.14	**$93,421.00**
			$132,346.00

Table 2: Estimated cost of implementation for the two bar code solutions

Estimated savings		
* Based on direct labour rate of $70/man hr. ** Based on a 5 day week and a 52 working week year. Note: All estimates are intended only to provide an idea as to the magnitude of savings possible and not to provide an accurate measure of the savings that would actually be achieved. It is not possible to consider all factors or suggest that the total time savings would necessarily translate to the estimated reduced labour requirements nor is it possible to quantify all possible savings from implementing a bar code solution.		
Receiving and storage		
Estimated number of items received on site	30,000	
Estimated time savings over manual method	3	Minutes per item
Estimated total labour savings	1,500	Man hrs
Total estimated cost savings*	**$105,000**	
Search and retrieval		
Estimated time spent searching per employee per day	20	Minutes per day
Estimated time spent searching per employee per year**	86.67	Hours per year
Estimated number of employees performing searches	5	
Estimated total labour savings	433.33	Man hrs
Total estimated cost savings*	**$30,333**	
	$135,333	

Table 3: Estimated savings from implementing a bar code system

5.1.4 Net Present Value (NPV) Analysis

A NPV analysis of the two proposed bar code solutions has been included to project the estimated profitability of the investments using discounted cash flows.

Assumptions: technology used on construction projects provide a consistent cash flow and incurs the same variable costs each year, occuring on the last day of the year; the technology invested in have an expected life of 5 years before replacement with no salvage value; and the assumed borrowing rate of the non-equity funded firm used as the cost of capital is 10%. The values used in the calculations have been taken from Table 2 and Table 3 above. Note: savings on materials replacement, rework and scheduling are not considered in this analysis as they are difficult to quantify but are expected to be very significant. It is believed that the value of implementing a bar code system is largely underestimated using this NPV analysis.

1) The estimated NPV for a thermal transfer bar code solution: n = 5 & r = 0.10

$$NPV_1 = I_0 + \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} = -\$32{,}000 - \$9{,}642 - \sum_{i=1}^{5} \frac{\$3{,}300}{(1+0.10)^i} + \sum_{i=1}^{5} \frac{\$135{,}333}{(1+0.10)^i} = \mathbf{\$458{,}867}$$

2) The estimated NPV for a metal bar code solution: n = 5 & r = 0.10

$$NPV_2 = I_0 + \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i} = -\$32{,}000 - \$38{,}925 - \sum_{i=1}^{5} \frac{\$93{,}421}{(1+0.10)^i} + \sum_{i=1}^{5} \frac{\$135{,}333}{(1+0.10)^i} = \mathbf{\$117{,}237}$$

5.2 Passive RFID System

After contacting a number of suppliers to discuss the merits of the promising RFID technology in tracking construction steel work, it soon became apparent that RFID would not be a viable solution.

5.2.1 Cost/Benefit Analysis

The performance of RFID is severely degraded in metal dense environments and its behaviour around metals can be described as anything but predictable. Given the magnitude of structural steel, how it is distributed to site, construction being a labour intensive exercise and assuming that all the readers are handheld devices operated by the site workers, then RFID would not appear to provide any realisable value over bar coding for this particular application. Presently, the most suitable passive RFID mount-on-metal tag identified was too large to be practical for use on steel work. This tag retails for around $14 per unit compared to metal and thermal transfer bar code labels that can be supplied at a cost of less than a dollar per unit.

6.0 Conclusion and Recommendations

The bottom line is that RFID cannot be confidently implemented to track steel work as it is just too uncertain. The author believes that the only presently available workable solution for tracking construction steel work within the perimeters of a construction site is bar code technology. The NPV analysis demonstrates that investing in either bar code system will add value to the firm over the life of the investment project. It is important to consider not only the cost of implementing a new system but the cost of not implementing one. The author recommends that thermal transfer and metal bar codes be purchased and tested to identify which one performs best for construction applications. Another promising solution not discussed in this paper that could be used as opposed to bar code labels involves directly marking parts with bar codes using lasers. Further investigation of this technology needs to be conducted to examine its applicability in use on steel work and how it ranks in comparison to other proposed solutions in terms of costs, benefits and limitations.

7.0 References

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