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Abstract

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Disciplines

Physical Sciences and Mathematics

Publication Details

This conference paper was originally published as Hamilton, D, Improving Inventory Control in a small-to-medium Retailer Using RFID, International Symposium on Communications and Information Technologies ISCIT 2007, 17-19 Oct, 1349-1354.

Improving Inventory Control in a Small-to-Medium Retailer Using RFID

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Abstract— Small-to-medium retailers are organizations that have traditionally had problems with inaccurate inventory control systems. This paper documents a research project that is currently in progress, aiming to explore the use of RFID for improving inventory control in a small-to-medium retailer. The aim of this paper is to review literature related to the project to emphasise its significance. In the initial part of this paper, the purpose of inventory control and the basic principles of RFID technology will be outlined. The latter part of this paper examines literature that has been published in relation to RFID and inventory control, highlighting areas that will be addressed by the research project.

I. INTRODUCTION

The aim of this research paper is to explore the use of Radio Frequency Identification (RFID) for improving inventory control in a small-to-medium retailer. Inventory control practices are significant to all organizations, especially small-to-medium retail enterprises [1]. These organizations employ more than 5 and less than 200 people and are characterised as having unreliable inventory control systems [2][3]. RFID is an emerging technology that is yet to establish or prove itself in retail organizations. Barcode systems have long been used for automated inventory control, however RFID has the potential to provide new opportunities and benefits to retail.

II. INVENTORY CONTROL

It is almost impossible to find an organization that does not use, transform, distribute or sell materials in one form or another [4]. Inventory control is relevant to all organizations from any sector of the economy [4]. Inventory control dates back to the dawn of time where the earliest humans used to stockpile food and stone tools. Presently inventory control is an essential part of organizations that is correlated to corporate success and failure [1]. Inventory is defined as material held by an organization awaiting sale, use or transformation [5]. Organizations hold inventory for a range of reasons including a lack of predictability or fluctuations in demand, unreliability in supply, to receive quantity discounts, to lower ordering costs, and to be subject to price protection through buying products at the right time. Purchasing, holding and possessing inventory subjects an organization to operational costs. According to Muller [5] the cost of holding inventory refers to financial, space, labour, deterioration, damage and theft aspects. Inventory control techniques can

be employed by organizations in order to minimize the burden of ongoing expenses. Inventory control can be defined as “the activity that organises the availability of items to the customers by, coordinating the purchasing, manufacturing and distribution functions to meet marketing needs” [6]. The aim of inventory control is to maximise customer service, profit and efficiency of purchasing and production, whilst at the same time minimising inventory investment [7]. Not all organizations have the same inventory requirements. Organizations that are classified as being retail, wholesale/distribution and manufacturing have differing needs and inventory issues.

A. Significance of Inventory Control to Retail Organizations

Retail organizations are the final link in the distribution channel, connecting the manufacturers and wholesalers to the customers, and are therefore subjected to inventory problems related to supplies and finished goods [4]. Effective inventory control is essential for retail organizations. Customers usually do not tolerate product shortages or delivery delays, especially if these events occur frequently. A company's reputation and market position will be eroded or compromised under these circumstances. Alternatively holding a large amount of stock can deplete the retailer's resources [1]. Successful retail organizations maintain appropriate inventory levels, as product shortages and over-stocked inventories are characteristic of companies that are not operating effectively.

III. INVENTORY SYSTEMS AND BARCODES IN RETAIL

Inventory systems are used by organizations to maintain control over their materials and products. Inventory systems are quite diverse and differ across many dimensions [1]. Fig. 1 depicts how inventory is subjected to both a supply and demand process and where technology is used to control it.

Fig.1 Inventory and the Supply and Demand Processes (Adapted [1])

Traditionally, to improve inventory control and inventory systems, organizations have semi-automated their processes through the implementation of barcode systems. Bar coding is a form of automatic identification that collects data through keyless means. The barcode is essentially a binary code that is comprised of a pattern of bars and gaps arranged in a parallel configuration [8]. The information stored by barcodes is captured in 'line of sight' by optical readers, one barcode at a time. The first bar code system was developed in the United States of America during the late 1940's by Sylvania/GTE applied Research Lab. This system was developed for the rail industry, aimed at controlling freight cars. The system utilised a white light optical scanning system to illuminate horizontal bars of reflective red, white and blue on non-reflecting black background [9]. Since its inception the barcode has been used in many different industries, including the military, health and insurance industries. Commercial use of the barcode came about during the early 1970's and became widespread during the 1980's and 90's [9]. Barcodes have become the most pervasive automatic identification technology over the past few decades as they have many advantages over other technologies. Barcodes are affordable, easy to use and have increased reliability and accuracy over manual collection techniques and other technologies [10]. Barcodes have also become highly standardized, especially in retail where the UPC/EAN standard is used by more than a million companies in 141 nations [10]. These advantages of barcode technology have translated into operational improvements in the form of superior data accuracy, efficiency, consistency and inventory and asset management within the organization [11].

A. Recent Trends in Retail Operations and Inventory Control

Over the past decade operations and processes carried out by organizations have changed, which has had implications for inventory control. Many Japanese firms have been able to operate with lower inventories than their western equivalents, sparking the trend of keeping inventories as lean as possible [1]. Practices such as just-in-time (JIT) inventory management and build-to-order (BTO) are outcomes of this new trend that have had implications for inventory control [10]. Wild [6] and Ellram et al. [11] believe that inventory

control and inventory management have developed rapidly due to the increasing focus on the customer, the more competitive environment and the wider use of information and communication technology. Zipkin [1] contributes to these beliefs stating that advances in technology have had a major influence on inventory control and that technology-enabled innovations in inventory control have the potential to restructure entire industries. Organizations are continually seeking ways to develop a competitive advantage through information technology.

IV. RFID TECHNOLOGY

A. RFID Basics

RFID can be defined as an electronic tagging technology that allows objects to be automatically identified at distance without direct line of sight, using an electromagnetic challenge/response exchange [12]. An RFID system primarily consists of RFID tags (transponders) and RFID readers, but can be extended to include antennas, radio characteristics and the computer network used to connect RFID readers [8][13]. Fig. 2 illustrates the configuration, components and interactions present in an RFID system.

Fig. 2 A Simplified RFID System

RFID readers contain radio frequency modules that emit pulses of radio energy that are detected by tags and responded to with information, such as the tag's serial number [8]. RFID tags are the labels that are attached to the object to be identified. RFID tags consist of an antenna, a small silicon chip that contains a radio receiver, a radio modulator, control logic, memory and a power system [13]. RFID tags are classified as being passive, semi-passive or active based on their composition. Passive tags are the most common tags, solely powered by the radio frequency signal that is used to transport information, whereas active tags are equipped with on-board batteries [13][14]. Semi-passive tags are passive tags that have had a battery added to boost signal range [15].

B. Advantages of RFID

The characteristics of RFID technology described previously differentiate them from other automatic identification technologies. One of the main physical advantages of RFID technology is that tags, unlike barcodes do not require line of sight to be read and multiple tags can be read simultaneously [16]. A field test carried out by UK retailer Marks and Spencer tagged 3.5 million bins and

recorded that it took just 3 minutes to read 25 trays when it used to take 17.4 minutes using barcodes, an 83% reduction in reading time for each bin. Dissimilar to barcodes, RFID systems are not affected by harsh manufacturing environments [8]. RFID systems are unaffected by dust, moisture, oils, coolants, cuttings, gases [8]. In addition to this RFID tags can operate in extreme temperatures and last for longer periods, in some cases longer than the items they are attached to [17]. RFID tags and systems are also characterized by having a greater data density and data quantity than traditional automatic identification technologies in the form of barcodes [8]. This allows RFID tags to carry unique serial numbers more easily than a barcode, which would require a long symbol or a two-dimensional variant, which is difficult to scan and fit into available space. A final major advantage of RFID systems is that they capture data in real time. Capturing data in real time allows organizations to improve data quality, as the information captured is more timely and accurate. All these advantages detailed have the potential to improve operations within commercial organizations.

C. Challenges of RFID

Studies and literature reveal that due to RFID's novelty in commercial and manufacturing applications, a number of challenges have created concerns about the feasibility of its implementation. The majority of problems that have been encountered when implementing RFID relate to technical and hardware issues [18]. Issues have been raised such as the reliability of RFID tag reads [17]. It has been discovered that when a tag is oriented perpendicular to a reader it is difficult to read it [12]. Jones et al. [16] and Michael and McCathie [17] state that radio waves can be absorbed by moisture in the immediate environment. Radio waves can be hidden, distorted or reflected by metal and the noise from electric motors and that fluorescent lights can also interfere with RFID communications.

In the past the cost of RFID technology has had an impact on its uptake as tags were considered to be too expensive, especially for item-level tagging [17]. However these costs are ever decreasing. The absence of global standards is another major problem of RFID as they are still developing through the formation of the EPC global network. To date systems have utilised multiple standards restricting interoperability [19][17][12]. Organizations that implement RFID systems must also review the information technology infrastructure they have in place, as a copious amount of real-time data is captured by these systems [16].

The final challenge of RFID relates to privacy concerns. As RFID is used to track items, privacy activists are concerned about the use of technology on retail items such as clothes which could allow retailers to send and receive information after items have been purchased [17][12]. Privacy concerns, like all the other issues identified in this section, require more attention for RFID to become widespread in the commercial and manufacturing industries.

V. PRESENT RFID IMPLEMENTATIONS

Although RFID's use is not widespread to date it has been used in applications such as highway bridge tolls, tracing livestock movements, controlling nuclear inventories, tracking air freight and motor vehicle manufacturing [16]. A paper by Angeles [15] provides seven case studies of companies and organizations in the manufacturing and logistics industries that have implemented RFID successfully. The falling cost of RFID and technological improvements have contributed to the technology becoming feasible for retail and logistical applications [16]. Large retail organizations that are currently experimenting with or testing RFID can be found all over the world. These organizations include Wal-Mart and Proctor and Gamble in the US, Marks and Spencer and Tesco in the UK, Metro AG in Germany, Coles Myer in Australia and Mitsukoshi of Japan. The US Department of Defence (US DOD) has recently mandated that its major suppliers adopt and implement RFID technology by the year 2005 [20]. Retail giant, Wal-Mart have taken similar actions mandating that its top 100 suppliers place RFID tags on all pallets and cases by 2005 [20][16][21]. In early 2003 Gillette became the first major manufacturer of consumer goods to place a huge order (500 million) for RFID tags and subsequently carried out an RFID/EPC trial in its US distribution centre [16]. An RFID test case was also carried out by UK retailer Asda to track and monitor CD sales [16]. This test case was aimed at increasing supply chain efficiency and anti-theft capability. The trial revealed that RFID could be useful for retailers but also highlighted a number of problems and issues with the technology, as well as a number of limitations regarding Asda's supply chain. Another UK retailer, Sainsbury's, carried out an RFID trial that revealed quantifiable benefits [22]. Although the study concluded, that based on estimated savings, the payback period for an RFID system would be around two to three years, Sainsbury's did not implement RFID at full-scale due to other business priorities that required addressing. Later in 2003, two other major UK retailers, Tesco and Marks and Spencer began trialing RFID, Tesco in its distribution centre and Marks and Spencer on its men's clothing range [16]. German retailer Metro AG has also launched a 'store-of-the-future' initiative, by implementing RFID in their supermarkets to enhance customers shopping experience. International convenience store conglomerate, 7-Eleven is also showing interest in RFID's potential [19].

VI. USING RFID FOR INVENTORY CONTROL IN A SMALL-TO-MEDIUM RETAILER

Literature to date regarding RFID and its implementation in a commercial context has been focused on the benefits it can provide retail organizations and its impact on the supply chain. Authors such as Symbol Technologies [23], Bhatt and Glover [24] and Bhuptani and Moradpour [25] have commented on the positive implications that RFID can have for retail organizations, in the form of cost reductions, increases in revenue and the automation of business processes. Many

authors have also stated that RFID has the potential to achieve greater efficiency and visibility in the supply chain by providing up-to-the-minute information in an ever-changing environment [23]. Other authors have had more negative views of RFID in the supply chain. Lefebvre et al. [19] states that RFID implementation will require a restructure of existing processes and greater electronic integration, while papers by Chuang and Shaw [26] and Michael and McCathie [17] note that upstream suppliers are concerned that RFID will not benefit them in the same way it does retailers, as they are being forced to absorb additional costs regarding tagging and the processing of information.

The latter parts of this section are dedicated to highlighting the areas and issues that the current research project will address that previous studies have not. The current research project addresses the limitations of previous literature by examining the use of RFID strictly for inventory control, using RFID in small-to-medium retailers and carrying out an empirical RFID study.

A. *RFID and Inventory Control*

RFID has been touted as a technology with the potential to improve current inventory control practices. According to Viale [7], "Inventory is a very expensive asset that can be replaced with a less expensive asset called 'information'. In order to do this, the information must be timely, accurate, reliable, and consistent. When this happens you carry less inventory, reduce cost and get products to customers faster." RFID's ability to provide real-time information can help provide retailers with the "timely, accurate, reliable and consistent" information that Viale [7] is referring to. This in turn will improve inventory control by helping organizations adjust to the recent changes in business operations, as outlined in section III-A, by moving from a push model to a pull model (where inventory is pulled from the supply chain by customer activity, not from inventory). Mills-Harris et al. [27] states that the "management of inventory should be robust yet sensitive to change with respect to varying demand patterns". This comment is satisfied by other authors outlook that RFID technology promotes tighter control of the supply chain and inventory management resulting in attendant cost savings, reduced labour costs, customer service improvements, shrinkage reduction, improved replenishment process and clearer targeting of customers and tracking of their purchasing behaviour [13][25][16]. There is an abundance of literature examining RFID's impact on supply chain management, but scant literature regarding its impact on inventory control. A paper by Kärkkäinen [22] found that RFID can provide significant benefits to an organization without supplier participation, based on an RFID trial at a major grocery retailer. However this paper was primarily concerned with increasing efficiency in the supply chain. Similarly, Albano and Engels [18] and Bendavid et al. [20] have used practical trials to emphasise the benefits that RFID has for inventory when implemented into the supply chain. Lee et al. [21] use a simulation model and subsequent quantitative analysis to gauge supply chain performance. The paper reveals that RFID technology can improve inventory accuracy, shelf

replenishment policy and inventory visibility, but its primary focus regards the supply chain like other papers previously mentioned. Angeles [15], Chuang and Shaw [26] and Nemeth et al. [14] also investigate the impact of RFID in the supply chain but through less practical methods. Angeles [15] outlines the main aspects of the technology and draws on example RFID implementation cases. Chuang and Shaw [26] also identify the impact RFID has on the supply chain by considering current implementation cases and utilise a well-known role playing simulation game (the Beer Game). However the findings of this study are more relevant to suppliers not retailers. Nemeth et al. [14] simply describes the benefits of RFID and its use in the supply chain.

All the papers discussed in this section are focused on RFID's impact on supply chains. The only papers that were found specifically relating to RFID and inventory control were aimed at detailed technical issues. A paper by Hu et al. [28] considers the use of a bitmap data type to support RFID item tracking, while a paper by Abraham et al. [29] presents the pros and cons of four different collision resolution protocols used by RFID enabled inventory control systems.

The current research project aims to inspect RFID and its implications on inventory control from a less technical perspective, revealing the benefits it can offer a small-to-medium retailer's inventory control practices.

B. *RFID and Small-to-Medium Retailers*

According to the Australian Bureau of Statistics [2] small-to-medium business employ a significant proportion of the working population making them important to the economy. Small retailers are characterised by little job specialization where the store owner is generally responsible for overall management and merchandising tasks. This characteristic of small-to-medium retailers has an impact on the level of formalization present in these organization's processes and operations. According to Gunasekaran et al. [3] small-to-medium enterprises, especially retailers have problems with unreliable inventory control systems, with poor stock tracing and cost control. These problems eventually lead to excess obsolete stock and eroding customer service levels. RFID is a technology that could potentially improve inventory control within small-to-medium retailers. However there is currently scant literature relating to RFID implementation in small-to-medium enterprises. As illustrated in section V and by authors such as Kärkkäinen [22] and Jones et al. [16], the majority of documented RFID trials and implementations have been carried out in large established organizations. The implications RFID has for large retail organizations and their supply chains is demonstrated by a quote taken from the research study carried out by Lefebvre et al. [19].

"The retail giant stands to save substantial amounts from supply chain optimization, Just-in-Time deliveries and the elimination of stock-outs since it will know exactly where all products are throughout its entire supply chain and could theoretically track any product from its supplier's supplier's location."

However, small-to-medium retailers are fundamentally different to larger established retailers and the effect RFID

has on these organizations has not been widely studied. Studying the impact of RFID has on inventory control in a small-to-medium retailer is more relevant than examining the technology's impact on the supply chains of these organizations. Small-to-medium retailers do not possess the bargaining power that larger established retailers have over their suppliers. For this reason, small-to-medium retailers looking to adopt RFID must implement it internally first for inventory control purposes. Once they have established their own RFID based system, interorganizational systems can be developed as soon as their suppliers are ready to employ the technology.

C. Empirical RFID Studies

A limitation in literature to date regarding RFID is the lack of research studies that utilize sound empirical approaches. A research study carried out by Bendavid et al. [20] uses a similar methodology to the one that will be employed by the current research project; a proof of concept. This study is carried out in an "open loop" supply chain, in a firm from the utility industry (electricity) and a first-tier supplier. Unlike the current research project, where the proof of concept is to be carried out in a real-life environment, the simulated scenarios of this study were created and carried out in a laboratory setting [20]. A study carried out by Lefebvre et al. [19] makes use of the same pilot study as Bendavid et al. [20] demonstrating RFID technology as a facilitator of B2B e-commerce. A recent research study by GS1 Australia [30] also used this approach [19][20]. This study involved many different logistical and manufacturing companies such as Gillette, Procter and Gamble and CHEP, to name a few. The study revealed benefits for all members of the supply chain and is more relevant to the current research project as it is carried out under local conditions, in Australia [30]. The studies by GS1 Australia [30], Bendavid et al. [20] and Lefebvre et al. [19] are significant as they practically evaluate RFID's use and the benefits it can afford organizations. The number of challenges associated with RFID, such as technical issues and others outlined in section IV-C can be addressed through practical studies such as those carried out by GS1 Australia [30], Bendavid et al. [20] and Lefebvre et al. [19]. Angeles [15] also highlights the need for practical studies in a recent paper as she concludes; "Research on the actual achievement of the promises of RFID and a more detailed understanding of effective implementation strategies and best practices now needs to be undertaken."

The current research project aims to further the research of the previously mentioned authors, address the current challenges facing widespread RFID implementation and the needs highlighted by Angeles [15]. The current research project will achieve this by carrying out a case study on a small-to-medium retail organization, involving a proof of concept RFID implementation.

VII. FUTURE STEPS IN THE PROJECT

The previous sections of this paper have identified some of the limitations of literature focused on RFID and inventory control. The current research project will attempt to address these limitations of the literature by carrying out a case study on a small-to-medium retailer, which will provide empirical evidence in relation to the benefits provided by RFID. The inventory control practices of a small-to-medium retailer will be identified by conducting interviews with employees and becoming a participant observer. Once the inventory control practices are identified, simulations will be developed that align the RFID technology with the business processes of the retailer. The simulations will demonstrate how RFID can be used in a retail setting for aspects such as replenishment, loss prevention, locating stock and checking orders and deliveries. The simulations will form the basis of a proof of concept focusing on the technical and operational feasibility of RFID in a small-to-medium retailer, examining issues such as tag read rates and the impact of environmental factors. A qualitative report will be developed to document the benefits demonstrated by the proof of concept approach and the impact of RFID on the small-to-medium retailer.

VIII. CONCLUSIONS

This paper has outlined the purpose of inventory control, the basic principles of RFID and recent RFID implementations. Examining the literature has highlighted the significance of the study, as previous studies have not examined the benefits RFID can provide exclusively for inventory control, nor have previous studies focused on RFID's impact on small-to-medium retailers. This paper has also revealed a need for comprehensive empirical studies that confirm the perceived benefits that RFID has for an organizations inventory control practices and related business processes.

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