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Chain

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Barriers to RFID Adoption in the Supply Chain

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Abstract—This paper explores the current barriers to adoption of radio-frequency identification (RFID) for supply chain applications, and documents the perceptions of key players in the Australian RFID market. The paper contains data collected from interviews of both technology providers (e.g. RFID vendors), and prospective business customer (i.e. a large retailer). Data collected is analyzed using qualitative content analysis, and supported with figures and tables. The findings show that the three main barriers to RFID adoption are: the cost of RFID implementation (especially ongoing tag costs), lack of customer awareness and education, and a technology which is only at the beginning of its lifecycle curve in terms of supply chain deployment. Prospective customers are also finding it difficult to justify a business case solely on RFID. Enter the idea of convergence between the long standing barcode and RFID technology. This paper argues that both technologies will co-exist in parallel, each with its specific function and set of advantages.

Index Terms—Radio-frequency identification, barcode, adoption, convergence

I. INTRODUCTION

This paper will explore the interplay between the retailer's dilemma of product shrinkage and the solutions advocated by RFID vendors and associations to minimize product shrinkage. RFID as an emerging technology holds the potential to fulfill the needs of stakeholders in the supply chain. The recent ratification of Generation-2 (Gen-2) RFID and the Electronic Product Code (EPC) standard developed by Global Standards One (GS1) has greatly influenced the adoption of RFID in certain industries. Despite these current standards supporting the growth of the technology, there still remain a number of challenges that prevent RFID from widespread adoption in the retail industry. These challenges involve overcoming barriers and inhibitors to the adoption of RFID implementation for the tracking of goods, especially at carton-level and item-level.

II. RFID: THE EMERGING TECHNOLOGY

Rivalry among businesses leads to the relentless pursuit of competitive advantage. According to research [1], across all industries 28 percent of organizations are planning to experiment with RFID technologies within the next two years. This interest in RFID technology suggests that it could also be

used by retailers for competitive advantage. Consider Michael Porter's [2] theory that well-established organizations are in the best position to integrate new technologies with SCM by leveraging existing assets (i.e. legacy barcode systems) to further support their investments. In this light, retailers willing to minimize product shrinkage, now have the ability to do so by complementing existing legacy barcode systems and other supply chain processes with RFID. Today, retailers and manufacturers are using RFID technologies to manage their supply chains (SCM). U.S. based companies such as Wal-Mart, Tesco, Target, Proctor and Gamble, and Gillette have implemented RFID technologies across their supply chains. According to the RFID vendors and associations involved in this study, RFID is currently used by Chinese and Korean airports, pharmaceutical industries and casino and gambling industries. RFID is a reality in these industries by the support of Gen-2 RFID standard of tag and EPCGlobal for data storage. However, even with the proliferation of RFID across a diverse spectrum of industries, it is yet to engage the Australian retail industry.

III. METHODOLOGY

A. Interviews: Vendors and Prospective Customers

Semi-structured interviews were conducted with RFID technology providers and employees of a large retailer. The job roles of each interviewee are listed: Loss Prevention Manager (1), Loss Prevention Investigator, Loss Prevention Manager (2), Liquor Manager, Grocery Manager, Store Services Manager, Store Trading Manager, Store Manager, Delicatessen Manager, Night-fill Captain, Customer Implementation Executive, Business Development Manager (Vendor 1), Systems Engineer (Vendor 2), Managing Director (Vendor 3), VP Marketing & Business Development (Vendor 4), Managing Director (Vendor 5), Managing Director (Vendor 6), National Sales Manager (Vendor 7), RFID Consultant, and Standards Development Coordinator. In total there were 20 interviews conducted in September 2006.

Interview transcripts were combined and then analyzed using the Leximancer content analysis software. Figure 1 illustrates the main concepts that were addressed by the interviewees, and the relationship of the concepts to one another based on their graphical proximity. The size of a circle which encapsulates a particular concept represents the relative importance of a concept and overlapping circles characterize association or closely allied concepts. The respective themes are defined in Table 1. The concepts shape the flow of the narrative.

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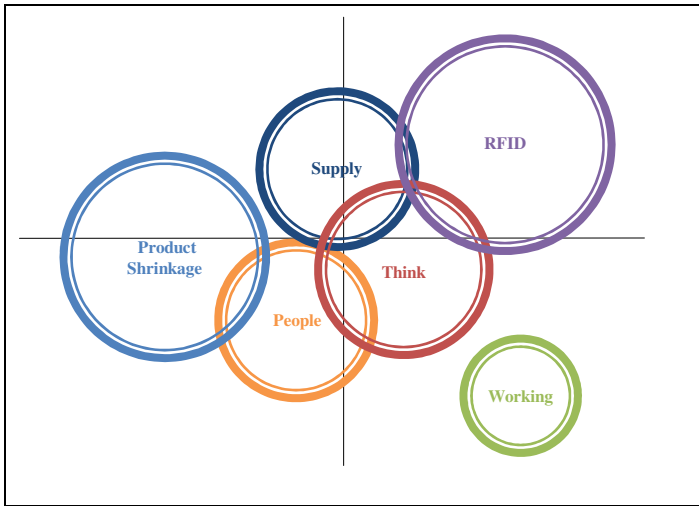


Figure 1. Leximancer Concept Map

Table 1. Discussion themes created from the concept map

Concept	Discussion themes
RFID	Primary theme and discussion topic including: <i>cost, immature technology, and differing perceptions of RFID.</i>
Product Shrinkage	Primary theme and discussion topic including: <i>the retailer's dilemma and differing perceptions of product shrinkage.</i>
Think	This theme represents the <i>lack of awareness</i> regarding RFID as a means to minimize product shrinkage. It also represents the <i>lack of education</i> of the contributing factors of product shrinkage.
Supply	The supply chain was a regularly occurring concept in interview transcripts. This theme represents the integration of RFID across the <i>retail supply chain</i> to minimize product shrinkage.
People	This theme represents the <i>retailer and the RFID vendors and associations.</i>
Working	It is important to recognize the isolation of this concept from other concepts on the map. This suggests that RFID is a <i>working</i> technology but is far from engaging the retail industry, especially as a means to minimize product shrinkage.

IV. BARRIERS TO ADOPTION

There are a number of challenges that are currently hampering the diffusion of RFID in the retail industry as a SCM solution and as a means to minimize product shrinkage. These barriers to adoption were identified as cost, lack of awareness, immaturity of RFID technology.

A. Cost

This study revealed that RFID is currently too expensive to be implemented by a retailer. The retailer's existing application of EAS tags to certain products is cost driven by the unit price or product lines deemed to be high-theft item targets. According to the retailer's Loss Prevention Manager (1), cost prohibits the investment of newer generations of RFID at this stage. Although the technology has improved dramatically over the past decade, the cost of various RFID components remains a significant inhibitor to its adoption. It

was agreed on by both the retailer and the RFID vendors and associations that cost was the most dominant barrier to the integration of RFID in a retail setting. In addition, RFID was dismissed as a possible SCM solution on most occasions solely based on this factor. As recognized by the Business Development Manager from RFID Vendor (1): "I think it'll take a fairly low cost tag and cost effective reader for them to implement an RFID system... the manufacturers of the technology are doing their best and investing a great amount of money into improving the technology. I think it's only going to get better and it's only going to get more cost effective, which means eventually it will be implemented."

RFID readers and tags were found to be costly outlays in an RFID implementation. However, RFID tags in a supply chain solution require constant replenishment. RFID readers on the other hand have an initial outlay, but in most cases require little maintenance. A large scale operation, such as integrating RFID within a retail supply chain, requires a large number of RFID tags, and the cooperation of all the entities in the value chain. Consequently, it was discovered that tags represented the larger expense of the two. The Systems Engineer from RFID Vendor (2) claimed: "[i]t's the tag cost that does sting, especially when you're comparing it to things like barcodes." The price of an RFID tag is relative to the law of economies of scale. Economies of scale refers to the decreased per unit cost as output increases [3]. In other words, when RFID tags can be produced on a larger scale with less input costs, economies of scale are achieved. The latest silicon technology and other advancements in RFID are to influence production volumes due to the lower costs of such materials (RFID Vendor 4). As illustrated in Figure 2, as the price of RFID tags fall and become more affordable, the adoption of RFID will increase. As predicted by RFID Vendor (2) "the magic number in the industry is 10 cents a tag" and retailers are more likely to see a return on investment with an RFID solution that is consistently cost effective. Prospective customers also need to change the way they are evaluating the business case for RFID in their organization. Traditional models focus on the cost-benefit justification between barcode and RFID, which is limiting in scope when one considers the high probability of convergence.

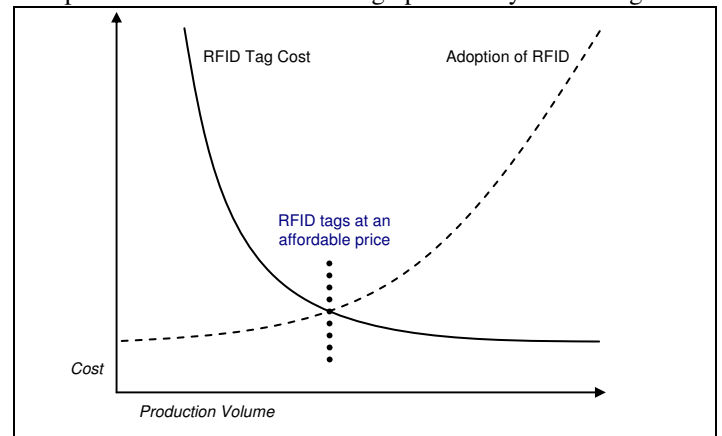


Figure 2. RFID adoption model (cost vs production volume)
Adapted (Kleist et al. 2006, p. 39 [4]; Lahiri 2006, p. 230 [5])

It is most likely that an RFID solution for a retail supply chain would need to integrate a middleware application. Middleware was also found to be an expensive component of an RFID system. As suggested by RFID Vendor (4): “you might need to get a middleware company involved like IBM or SAP and that’s where your large costs are.” Many vendors were providers of hardware-based solutions and relied on a third party to integrate middleware and the communication between RFID tags and a Warehouse Management System (RFID Vendor 2). It was therefore confirmed that the overall costs involved in an RFID implementation are a barrier to its adoption. The technology may exist to build an RFID solution for a retail supply chain, yet it all comes down to developing business cases (RFID Vendor 3) and improving the general awareness of the technology in the industry.

B. Lack of Awareness

Another commonly occurring concept was “think” which represents the lack of awareness of RFID technology, and the hesitation that prospective customers have about their RFID vision. It was found that the overall awareness of Gen-2 RFID within the retailer studied was generally low. Loss Prevention staff members had a reasonable understanding but failed to recognize the true potential of RFID as a retail SCM solution and an effective loss prevention mechanism. This lack of awareness requires information sources to be directed at retailers to instigate a solution. The RFID Association involved in the study was a non-profit organization, solely established to increase awareness of RFID through communication and forming a knowledge base. An interesting point raised by the RFID Consultant was that RFID “brings different knowledge into the same room”. This suggests that integrating RFID across the supply chain may require more than just the retailer and an RFID vendor. Other stakeholders, such as standards bodies, government agencies, product manufacturers, logistics companies, wireless and other innovative technology providers need to communicate. One way to do this is to form a consortium.

Table 2. Australian Demonstrator Project [6]

Participant Name	Description
GS1	Standards body (EPCGlobal, EAN, UPC)
CSIRO	Deliver science and innovative solutions for industry
Australian Food & Grocery Council	Represents food & grocery product manufacturers
Linfox	Logistics company
Chep	Transport, pallet and container services
Proctor and Gamble	Multinational manufacturer of consumer goods
Capilano Honey	Honey manufacturer and international exporter
MetCash	Independent retail organization
Nugan Estate	Producers of wine and olive oil
Sun Microsystems	Information technology, data storage and hosting
Verisign	Secure online trading

As quoted by RFID Vendor (1), “there really has to be a business case, and I think people really need to understand that”. So far, the Australian retail industry has only witnessed the Australian Demonstrator Project, chiefly conducted by Global Standards One (GS1) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) [6]. The study involved numerous participants (Table 2). As part of a pilot study, these participants set out to discover the benefits of RFID in a retail supply chain environment. The project formed a business case with a principal finding that internal knowledge and the use of standards is essential to a successful RFID implementation [6]. The study also advised that it is important that retailers in search of similar solutions investigate their own business challenges [6]. This could be made possible via the formation of consortiums and the establishment of a common goal through forming agreements or industry compliance mandates.

C. Immature Technology

To become a well established and accepted technology, like barcode, RFID needs further development. As acknowledged by RFID Vendor (4) retailer’s have “got some pretty good systems that have matured over time and it would be difficult to see where RFID could actually improve those systems.” In this instance, the vendor is referring to legacy barcode systems. RFID Vendor (1) also supported this idea: “retailers have invested an immense amount of money in moving their products from their distribution centers out to their stores and they do that quite well in this point in time.”

The suppliers of RFID equipment are also limited. For example, the Managing Director of RFID Vendor (5) claimed that his company is the only manufacturer in Australia for ultra long-range active tags. Using advanced battery management technology, similar to that of mobile phones, this type of tag has a battery life of seven to eight years (RFID Vendor 5).

When asked whether RFID was hype or reality, the RFID Standards Body claimed that it is “somewhere in between”. In the case of Wal-Mart in the United States RFID is a reality (RFID Standards Body). However, in Australia, even though we consider RFID a reality, there are only fifteen major deployments including toll-ways on motor highways (RFID Standards Body). Conversely, RFID Vendor (5) responded:

“[i]t’s a reality, definitely a reality... there’s very, very few people that are actually providing solutions. There are a lot of people that are supplying tags, readers, technology and what have you. But you go and approach them and ask them how to solve a particular problem, they’ll go huh? You’ll have to go see an integrator to do that. Where are these integrators? So, unfortunately in that regard the industry is in its infancy. It’s only some of the big players that are only interested in the multi-billion dollar deals with the likes of the Department of Defense and Wal-Mart that are really getting into this. Down at the normal level, there are very few players that provide an actual solution. We’re one of the few that do.”

In this light, RFID may well be a reality, yet in an Australian context it is still considered to be in its infancy. The barriers to entry expand even further when considering user perceptions of the technology but these factors are already addressed in the literature.

V. RFID AND PRODUCT SHRINKAGE- DIFFERING VIEWS

The retail organization found product shrinkage to be an issue that is over-looked by some employees working within retail outlets. As emphasized by the Loss Prevention Investigator, “retail sales are more important or considered more important, and Store Managers tend to focus more on sales and trying to get sales.” Whereas, a Loss Prevention Department is solely focused on preventing loss through theft, fraud and poor work disciplines (Loss Prevention Investigator). Therefore, it could be advised that both Store Managers and Loss Prevention Departments work towards a common goal in an effective loss prevention strategy. Furthermore, he also claimed: “I don’t think they fully understand that one dollar in shrinkage, they need to sell forty dollars worth to regain that gross profit.”

The RFID vendors and associations had differing views of product shrinkage. Whilst some thought that it only included misplaced and damaged goods, other vendors had past experience in the retail industry and thus a broader perspective of product shrinkage. It was found that product shrinkage was considered by the majority of vendors as a primary reason to adopt RFID. However, when RFID vendor (6) was asked about his perceptions of product shrinkage as a driver to adopt RFID, he disagreed: “No, no. Everyone quotes that the Wal-Mart experience and their issue is, they don’t know where there stock is and they have out-of-stocks. So they are able to use RFID to locate stock within their warehouse and environment and get visibility. The whole thing’s about getting visibility in the supply chain.”

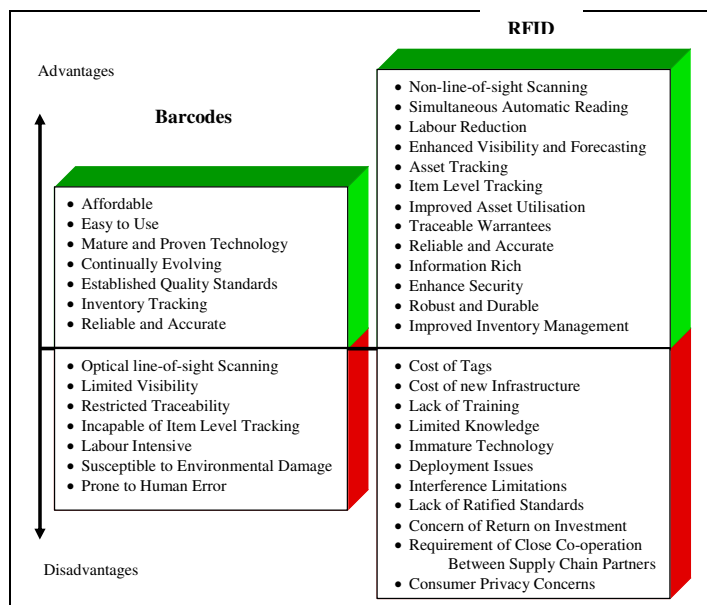


Figure 3. Dis(advantages) of Barcode and RFID

VI. THE CONVERGENCE OF RFID AND LEGACY SYSTEMS

Australian retailers have invested large amounts of time and capital into refining their existing legacy barcodes systems. What was highlighted by numerous RFID vendors and associations involved in the study, is the inevitable convergence of RFID and barcode systems, suggesting that both technologies will be integrated into the retail supply chain (Figure 3 and 4). The Managing Director (RFID Vendor 6) mentioned that he would be very surprised if barcode systems were ever phased out completely. The future potential for barcodes to operate in conjunction with RFID as a backup system was also envisaged (RFID Vendors 3-6). The RFID Consultant from the RFID Association also stressed the importance of smart labels. A smart label is an adhesive label with a barcode and an RFID tag. This technology is designed to support cross-compatibility between barcode and RFID systems within a supply chain configuration. Dual compatibility of smart labels has required the development of a new standard for data storage.

Technology standards also need to converge if RFID and barcodes are to coexist. The Standards Development Coordinator from the RFID Standards Body was asked about the convergence of UPC, EAN and EPC standards. He explained that EAN and UPC form part of the EPC standard which is known as tag data standards (RFID Standards Body). Uniting barcodes and RFID using smart labels and tag data standards facilitates a transition period from a combined barcode and RFID solution, to RFID only. However, RFID Vendor (6) predicted an ‘RFID only’ solution for a retail supply chain to be highly unlikely.

A. Level of Tagging

RFID tags can be applied to objects at various levels. The three main levels include: item-level, carton-level, pallet-level and container-level (RFID Vendors 1-7; [7]). The most appropriate level of tracking depends on the application and the industry vertical in which a solution is to be implemented (RFID Vendor 2). According to the RFID Standards Body, the most realistic application for a retailer at this stage is carton-level or pallet-level tracking. This type of tracking monitors individual cartons or groups of cartons on a pallet.

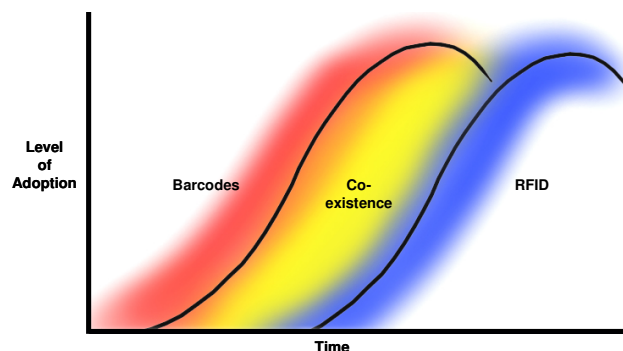


Figure 4. The Barcode and RFID Adoption Lifecycles

Comparison of Characteristics	BARCODES	RFID
Cost	Relatively cheap, as the technology is quite mature.	Expensive, although costs are expected to drop significantly as uptake increases and economies of scale are created.
Ease of Use	Simple and easy to use with little or no training required.	The removal of human intervention and the level of automation negates any operating difficulties
Ongoing Innovations	Although barcodes are a mature technology, there are still continual innovations in the technology such as mobile phone barcode scanners and multimedia messaging service (MMS) barcode tickets such as "mobi-ticket".	RFID development is at a relatively immature state which means new applications are continually emerging.
Reliability and Accuracy	Barcodes are quite reliable and accurate, but are subject to operator mistakes and environmental hindrances.	Some initial read reliability and accuracy issues have been discovered through pilots, however these are being solved as the technology matures. The technical nature of RFID and lack of human involvements means that theoretically its reliability and accuracy will be extremely high.
Line-of-sight	Barcodes are limited by line-of-sight optical scanning. Consequently, objects often have to be manually manipulated through human intervention.	The radio nature of RFID means tags can be scanned remotely through packaging. It also leads to simultaneous reading where large numbers of items can be scanned within seconds.
Information and Data Properties	Traditional barcode symbologies only hold a minimal amount of information. Symbology innovations like two-dimensional (2D) and reduced space symbology (RSS) allow more information to be stored. Their uptake has been limited.	Tags can typically hold as little or as much information as required by users, although this is limited by cost. Tags will allow for each individual item in the supply chain to be uniquely identified. In addition to this, tags can be updated as they move along the supply chain creating an audit trail.
Environmental Considerations	A significant limitation of barcodes is the environment. As barcodes have to be in view of scanners they are subject to damage, weather and other stresses associated with movement across the supply chain.	RFID tags can be very durable with some tags withstanding harsh chemical and extremely high temperatures. They are not subject to weather, nor are they typically damaged by rough handling, as they are stored inside packaging with the product.
Asset Tracking	Barcodes can be used to track assets, enabling businesses to monitor the use of many investments such as tools.	RFID tags allow organizations to track their assets as they are used. Tags can be attached to returnable items such as beer kegs to help maximize their use.
Inventory Tracking	Limited inventory tracking is available; however, barcodes can generally only specify what type of product an item is, limiting its effectiveness.	The individual tracking of objects as they move along the supply chain is easy with RFID. The information on tags can also specify a product's expiry date.
Inventory Management and Visibility	Inventory control is one of the primary reasons for using barcodes in SCM. They provide better visibility, allow management systems to better forecast demands, and manage stock on hand, utilizing practices such as just in time inventory management.	Once fully deployed, RFID would provide organizations with an accurate picture of inventory levels in real-time. This allows management systems to act with enhanced knowledge and monitor all inventory details to maximize efficiency.
Quality Control and Recall Management	The inability to track unique items across the supply chain means that recalls and quality control cannot be very accurate.	Individual item level management allows organizations to undertake stringent quality control practices and make very specific recalls when required. Tags can also monitor shock and temperature levels to ensure the quality of the end product.
Level of Visibility	The requirement of manual scanning at many SCM phases limits the availability and timeliness of information.	Non-line-of-sight properties allow the continual monitoring of objects, which equates to real-time visibility.
Security	Barcodes provide limited or no security capabilities.	Information rich, always-on tags give organizations the ability to constantly monitor tagged objects. Should an item go missing in the supply chain, systems can immediately initiate the appropriate response. Tags can also authenticate products to ensure they are not counterfeit.
Error Reduction	Compared to manual data entry, barcodes can reduce errors significantly. However as the scanning of barcodes is a physical process, human error can creep into the process with staff forgetting to scan items.	RFID is highly automated and when setup correctly can achieve near perfect read rates. Automation removes the need for human manipulation, further lowering errors.
Cost Savings	Barcodes can help companies improve inventory management and efficiency; however, the physical scanning requirement of barcodes means that a large labor component is required.	Once fully integrated into the supply chain, RFID could substantially lower operating costs and improve efficiency, reducing problems such as out-of-stock occurrences.
Labor Considerations	Provides a reduction compared to manual data entry, although scanning items still requires a sizable labor contingent.	Automation directly eliminates a substantial labor component from SCM. As the technology becomes more pervasive, further labor reduction could be achieved through things like automated checkouts and smart shelves.
Deployment Considerations	Aside from environmental factors, there are few deployment considerations as the technology is inexpensive and widely used.	Radio interference can prove to be a major issue in deployment, requiring numerous pilots and testing. The cost of RFID deployment and training are some other considerations.
Established	Barcodes are highly developed and are the standard in auto-ID SCM technology. It will be around for quite some time.	RFID has a limited number of deployments in SCM. Despite this, recent mandates from leading companies mean that in the near future the technology will be used extensively.
Privacy Concerns	The barcodes inability to track individual items limits consumer privacy concerns.	Tags are information rich and as they are quite durable, they can remain active for the lifetime of many products. The pervasive 'always-on' nature of the technology has caused concern among many privacy advocates.

Other than the inhibitor of cost previously mentioned, item-level tracking is presented with a number of problems including read ranges and the complexity of integration throughout the entire supply chain (RFID Vendor 2; RFID Standards Body; see table 3 comparison of characteristics between barcode and RFID). However, the Vice President of Marketing and Business Development (RFID Vendor 4), suggested that item-level tracking is definitely an enabling technology in areas such as; access control and asset tracking but, “it doesn’t make sense to put them on cans of beans or on clothes where barcodes are suitable.”

A. RFID Source-tagging

Retailers drive their EAS source-tagging initiative by forming agreements with their suppliers. This initiative currently focuses on EAS anti-theft tags that are applied at point of manufacture and play a minor role in SCM processes. A high-end product may come source-tagged, but the tag’s only function is to operate at store entry and exit points solely as an anti-theft mechanism. Consequently, the retailer’s Store Trading Manager claimed that EAS does not minimize product shrinkage to a significant level. Preliminary EAS agreements between suppliers and retailers may create the foundations for future agreements for an RFID enabled supply chain. This topic is closely linked to the notion that awareness and the formation of consortiums play a large role in the tagging of products at the point of manufacture. It was recommended by all RFID vendors and associations involved in this research that a successful RFID implementation requires the participation of all parties involved in a retail supply chain.

VII. INTEGRATING RFID ACROSS THE SUPPLY CHAIN

The levels at which products are to be tagged for distribution across the supply chain needs to be determined prior to the implementation of an RFID solution. When considering item-level tagging RFID Vendor (4) proposed the following: “[t]he whole benefit of barcodes wasn’t established until everything had a barcode on it. So if you’re going into a retailer and say I’ll tag all the expensive stuff, but I won’t tag all the cheap stuff, then they’re not really utilizing the benefits of RFID, you really have to tag everything, because otherwise you’ve got to have two systems- a system for the products that are tagged and one for the products that aren’t tagged.” Furthermore, RFID needs to be implemented across the entire supply chain to function in this manner, i.e. at the item-level, and “[t]hat’s where the real effort comes in” assured the Systems Engineer (RFID Vendor 2). Setting up a system at a distribution centre with over thirty truck bays can be extremely complicated (RFID Vendor 2). From a hardware perspective, testing and fine-tuning RFID solutions regularly encounters issues such as cross-over, multiple reads and other types of read errors (RFID Vendor 2). The task becomes “hugely complicated if we’re talking about a full supply chain” (RFID Vendor 2).

VIII. CONCLUSION

This paper discussed the current issues surrounding RFID as an emerging technology for a SCM solution and as part of a loss prevention strategy for a retailer. Primary themes discussed included the barriers to RFID adoption, encompassing the costs involved, lack of awareness, RFID as an immature technology and the differing perceptions of product shrinkage and RFID. As each barrier to entry was examined, reciprocal relationships were found to exist between the retailer and RFID vendors and associations involved in this study. Investments made by retailers in legacy systems, was found to influence the convergence of RFID and barcodes supported by smart labels and tag data standards. With the various levels of RFID tagging available, it was determined that both pallet-level and carton-level tracking were most appropriate for an Australian retail application. Building upon business cases like the Australian Demonstrator Project and forming consortiums was found as a primary instigator to the future deployments of RFID. Source-tagging products at the point of manufacture was also supported by both the retailer and RFID vendors and associations as a means to minimize product shrinkage at various point across the supply chain, other than point of sale. These types of initiatives are likely to reinforce the overall success of an RFID SCM solution as part of a loss prevention strategy. Finally, it was discovered that the incorporation of retail supply chain stakeholders is critical to the overall effectiveness at which an RFID solution can function in order to minimize product shrinkage.

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