2004

The advantages and disadvantages of barcodes and radio frequency identification in supply chain management

L. McCathie
University of Wollongong

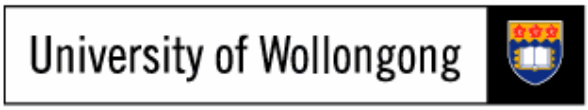
Publication Details

This thesis was originally submitted as McCathie, L, The advantages and disadvantages of barcodes and radio frequency identification in supply chain management, Bachelor of Information and Communication Technology (Honours), University of Wollongong, 2004, 123p.

The advantages and disadvantages of barcodes and radio frequency identification in supply chain management

Abstract
Since the 1980s, barcodes have become the backbone of supply chain management (SCM). Recently organisations, from both government and corporate sectors have placed increasing emphasis on further streamlining SCM to deliver cost savings. This has lead to a number of leading organisations introducing mandates for their suppliers to implement radio frequency identification (RFID) technology. Many organisations are unsure which technology, barcodes or RFID offers them the best return. This thesis will aid stakeholders in understanding the advantages and disadvantages of each respective technology in SCM applications. Furthermore, the research will examine the importance of a global standard for RFID such as the Electronic Product Code (EPC) and offer insight into the coexistence of barcodes and RFID. The research will employ a thorough documentation review as well as several interviews with users of each technology.

Publication Details
This thesis was originally submitted as McCathie, L, The advantages and disadvantages of barcodes and radio frequency identification in supply chain management, Bachelor of Information and Communication Technology (Honours), University of Wollongong, 2004, 123p.



School of Information Technology and Computer Science

The Advantages and Disadvantages of Barcodes and Radio Frequency Identification in Supply Chain Management

Author – Luke McCathie
2264419

Supervisor – Dr Katina Michael

ABSTRACT

Since the 1980s, barcodes have become the backbone of supply chain management (SCM). Recently organisations, from both government and corporate sectors have placed increasing emphasis on further streamlining SCM to deliver cost savings. This has lead to a number of leading organisations introducing mandates for their suppliers to implement radio frequency identification (RFID) technology. Many organisations are unsure which technology, barcodes or RFID offers them the best return.

This thesis will aid stakeholders in understanding the advantages and disadvantages of each respective technology in SCM applications. Furthermore, the research will examine the importance of a global standard for RFID such as the Electronic Product Code (EPC) and offer insight into the coexistence of barcodes and RFID. The research will employ a thorough documentation review as well as several interviews with users of each technology.

Please Note: An abstract of this paper was accepted by CollECTeR Latin America, Santiago, Chile, 2004.

Table of Contents

LIST OF TABLES

LIST OF DIAGRAMS

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor, Dr Katina Michael. The time she has spent providing guidance, feedback and help throughout the year is greatly appreciated.

I would also like to thank my family for the support they have provided me, not just over the past year, but throughout my life.

ACRONYMS

2D	Two Dimensional
AIAG	Automotive Industry Action Group
AIM	Automatic Identification Manufacturers
Auto-ID	Automatic Identification
CIM	Computer Integrated Manufacturing
EAN	European Article Numbering
EIA	Electronic Industries Alliance
EPC	Electronic Product Code
HIBCC	Health Industry Business Communications Council
ICT	Information and Communication Technology
ISO	International Organisation for Standardisation
JIT	Just In Time
MMS	Multimedia Messaging Service
MRE	Meal Ready to Eat
PDA	Personal Digital Assistant
POS	Point of Sale
RFID	Radio Frequency Identification
RSS	Reduced Space Symbology
SCM	Supply Chain Management
TQC	Total Quality Control
UCC	Uniform Code Council
UPC	Universal Product Code
UPS	United Postal Service
WMS	Warehouse Management System

Chapter 1 - Introduction

1.1 Overview

This thesis is concerned with the eBusiness field and will discuss applications of two automatic identification (auto-ID) technologies, barcodes and radio frequency identification (RFID), in supply chain management (SCM). SCM is the "management and control of all materials and information in the logistics process from acquisition of raw materials to delivery to end user".[1] Continual improvement of SCM has been a key focus in many organisations for some time now and has lead to significant cost savings. The competitive nature of organisations drives the demand for new auto-ID technologies that will pave the way for improvements to SCM, which lead to the prevalence of barcodes. Barcodes are "printed horizontal strips of vertical bars used for identifying specific items".[2] The technology has been paramount in streamlining SCM, but its use can be labour intensive, as it needs line-of-sight to scan items. This inherent characteristic generally requires items to be manually manipulated prior to being scanned, subjecting the process to the possibility of human error. In addition, the information offered by a barcode is limited as common standards can only identify a product type. The thesis will identify the advantages and disadvantages of barcode and RFID technology in SCM and observe how barcodes became the principal auto-ID technology used to streamline SCM procedures.

1.1.1 The Rise of Radio Frequency Identification

The thesis will identify RFID as an alternative technology to barcodes in SCM. RFID uses "tags that emit radio signals and devices called readers that pick up the signal", with the ability to hold large amounts updateable information and is not limited by optical scanning.[3] RFID technology has opened the door to a new era in SCM, unachievable using existing barcode technology.[4] Leading corporations have

[1] CSX World Terminals, LLC. 2001. [Online] <URL: http://www.csxworldterminals.com/Resources/Glossary.asp?s=s> Last accessed 11/3/2004.
[2] Library of Automation 2003. [Online] <URL: http://www.libraryhq.com/glossary.html#B> Last accessed 16/3/2004.
[3] EPCglobal, Inc. 2003. [Online], <URL http://www.epcglobalinc.org/about/faqs.html#6> Last accessed 11/3/2004.
[4] "Radio Frequency Identification (RFID) stands poised to fundamentally change supply chain management". VeriSign 2004. *The EPC Network: Enhancing the Supply Chain*. VeriSign Whitepaper,

recognised the intrinsic advantages of RFID and recently moved to introduce the technology in SCM by establishing a mandate, forcing suppliers to use RFID. There is limited information comparing barcodes and RFID for use in SCM due to its sudden thrust into the limelight and as such, this thesis will examine the advantages and disadvantages of RFID in SCM and demonstrate that to realise the full potential of RFID technology, a global standard is essential.

To enable the seamless transition of products using RFID tags through all stages of the supply chain, the tags require a robust and widely accepted standard. The Electronic Product Code (EPC) standard "ensure[s] that products can be identified regardless of which manufacturer tags them" and will most likely become the dominant RFID standard in SCM.[5] It is a more detailed standard than the Universal Product Code (UPC) and European Article Numbering (EAN) symbologies used by barcodes as it can identify every individual product and provide other information such as expiry dates. For this reason, the thesis will also identify the role that the EPC standard will play in aiding RFID technology to deliver benefits to SCM.

1.2 Purpose

1.2.1 Significance

Barcodes have become a universal tool used by organisations in SCM since the early 1970s and it is now a multi-billion dollar business.[6] However, mounting pressure from a variety of areas is driving organisations to further increase efficiency, which has lead to the rise of RFID. Financial markets demanding that companies use capital more efficiently and with the advent of new technologies such as the Internet, consumers now have the ability to compare prices around the globe, sparking a price war among retailers. Business need to be mindful of this trend as it will inevitably lead to tighter profit margins.[7]

[Online]. <URL: http://www.verisign.com/nds/directory/epc/epc_whitepaper.pdf> Last accessed 1/3/2004.

[5] EPC Global Inc. 2003. [Online] <URL: http://archive.epcglobalinc.org/aboutthecenter.asp> Last accessed 11/3/2004.

[6] Adams Communications 2002. *Barcode History Page*, [Online] <URL: http://www.adams1.com/pub/russadam/history.html> Last accessed 7/3/2004.

[7] SAP White Paper. 2002. *Supply Chain Networks*. [Online] <URL: http://www.sap.com/solutions/scm/brochures/ note: no direct link available> Last accessed: 4/3/2004.

RFID offers a completely new range of applications that vendors (e.g. Zebra Technologies) claim will lead to improved SCM. While there have been many successful rollouts of RFID technology, few have been related to SCM. Those applications that have been for SCM purposes have typically been used exclusively for internal organisational purposes such as asset management. There is still reluctance in the business community to invest large amounts of capital in such new technology that is yet to prove itself in the long-term. Compounding this reluctance is the fact that many of these businesses have invested heavily in legacy barcode systems. There is a preference to use a cautious approach, waiting to see what global business leaders do. This is particularly evident in smaller companies, who are delaying announcements regarding the new technology. However, now that several significant market leaders such as Wal-Mart and the U.S. Department of Defence have announced deadlines for their suppliers to comply with RFID specifications, there is an increased urgency in the business community to explore the potential advantages and disadvantages of RFID compared to traditional barcode technology. Businesses need to know the advantages and real world value of RFID over their existing barcode infrastructure as deploying RFID is costly and time consuming. This thesis will report on these advantages and disadvantages for organisations, providing a comparative analysis of the two technologies to assist them in realising the importance of RFID and deciding what course of action is best suited to their organisation.

1.2.2 Objectives

The list of objectives below has been developed to guide the research and quantify the aims of the thesis.

1. To review literature on eBusiness with a view to identifying cases in the use of barcode and RFID technology in SCM.
2. Use the outcomes of objective one to identify a gap and a suitable methodology for investigating the advantages and disadvantages of barcodes and RFID in SCM.

3. Explore the advantages and disadvantages of barcodes and RFID in SCM using the methodology developed in objective two, which will utilise a documentation review and interviews of market stakeholders.
4. Identify the drivers for RFID uptake and discuss how the adoption of barcodes and RFID will evolve.

1.3 Justification

1.3.1 Previous Research

An initial review of the literature identified few papers in the area, as the technology is relatively new. Some of the works reviewed have been cited in Table 1.1. Numerous articles cover SCM or barcode technologies but fall short of exploring the complementary relationship that they share. An example of this would be LaMoreaux[8], or Collins & Whipple[9], both thoroughly covering barcode equipment and its implementation, but failing to discuss alternative auto-ID technologies like RFID. Similarly, the SoftChain[10] whitepaper talks about the need to improve SCM and the areas where inefficiencies are common, but aside from it suggesting its SCM software, it does not delve into the technologies that will allow the discussed improvements to SCM.

Table 1.1: Previous Research

Topic	Author
RFID Technology	Ames ed. 1990; Boone 2003; Finkenzeller 1999; Gerdeman 1995; Hudson 2004; Masters 2003; Michael 2003; Savi Technology 2002; Zebra Technologies 2004.
SCM Concepts	Aedy 2004; AP White Paper 2002; Mcnerney 2003; SoftChain 2002; Kumar 2001; Tompkins 2003; Wu & Ulieru 2000.
Barcodes	Brown 1997; Cohen 1994; Collins & Whipple 1990; Geers 1994; Harmelink 1993; Hind 1994; LaMoreaux 1998; Vernon 2003; Wenter 1994.
EPC Standard	EPC Global, Inc. 2003; Brock 2001; LXE, Inc 2003; Mullin 2002; VeriSign, 2004; Sun Microsystems, Inc 2003.

[8] LaMoreaux, R D. 1998. *Barcodes and Other Automatic Identification Systems*, Pira International, New York.
[9] Collins, D. J. & Whipple, N. N. 1994. *Using Bar Code- Why It's Taking Over*, Data Capture Institute, Massachusetts.
[10] Softchain. 2002. *Improving Extended Supply Chain Performance Through Better Control*. 7pgs. [Online]. <URL: http://www.manufacturing.net/scm/contents/pdf/softchain_wp.pdf>. Last accessed 1/3/2004.

There is a number of articles on RFID that mostly explain the technical side of the technology such as Finkenzeller[11] and Savi Technology[12], but these fall short of discussing RFID applications in SCM. Gerdeman[13] provides great examples of industrial applications of RFID but again, does not allude to SCM applications. Other works avidly discuss auto-ID technologies like RFID and barcodes and the role that they play in aiding the process of automation such as Michael[14] but do not go on to converse the role and inner workings of how these technologies are used to streamline SCM.

There are a limited number of articles, predominantly whitepapers, which often solely promote RFID technology in relation to SCM. These articles typically neglect the examination of how RFID will affect the current use of barcode technology, which is an important consideration for many organisations. Most of these articles provide innovative concepts for applying RFID technology but fail to investigate these ideas in relation to the "bigger picture" of SCM; often opting to only promote end solutions. Zebra Technologies[15] whitepaper optimistically promotes the use of RFID to solve business problems with innovative applications, however the desire to publicise Zebra Technologies' product solutions is evident throughout and taints the objectiveness of the article. These revolutionary applications often overlook the means for such deployments and the requirement of a global standard for RFID such as the EPC. Information on the Universal Product Code (UPC) and the story explaining how it was formed to be used in conjunction with barcodes is available and offered in the work of Brown[16]. However, there is an absence of literature in the area of RFID standards such as the EPC standard. Almost all such articles come from EPCglobal or AimGlobal, which are both industry associations.

[11] Finkenzeller, K. 2001. *RFID Handbook: radio-frequency identification fundamentals and applications*, John Wiley & Son, New York.
[12] Savi Technology. 2002. *Active and Passive RFID: Two Distinct, But Complementary, Technologies for Read-Time Supply Chain Visibility*. [Online]. <URL: http://www.savi.com/solutions/whitepapers/RFID_whitepaper.pdf> Last accessed: 5/3/2004.
[13] Gerdeman, J. D. 1995. Radio Frequency Identification Application 2000: a guide to understanding and using radio frequency identification. Research Triangle Consultants, North Carolina. pp. 89 – 197.
[14] K. Michael. 2003. The Auto-ID Trajectory, PhD Thesis, University of Wollongong.
[15] Zebra Technologies. 2004. *RFID: The Next Generation of AIDC* [Application White Paper]. [Online]. <URL: http://www.zebra.com/whitepapers/11315Lr2RFIDTechnology.pdf>. Last accessed: 3/3/2004.
[16] Brown, S. A. 1997. Revolution at the Checkout Counter: the explosion of the bar code, Harvard University Press, London.

1.3.2 The Gap

There is a lack of research, especially of an academic nature, which covers the advantages and disadvantages of existing barcode technology and emerging RFID technology, in relation to SCM. The vast majority of articles are whitepapers written by industry players who have a vested interest in promoting their products and services to industries. These whitepapers do not espouse recognised research methods (if any at all) and lack academic review. Many of the other reviewed works delve into niche topics or are too general. This thesis will make its contribution in bringing all the important issues together. This research is important as it intends to clearly address the gap in current literature and identify the advantages and disadvantages of barcode and RFID technology in SCM. It will also identify how the deployment of RFID will converge or coexist with barcodes and will also refer to the need for a global standard such as the EPC Standard.

1.4 Research Design

The research will employ a qualitative strategy that will identify and compare the advantages and disadvantages of barcode and RFID technology in SCM. As described in chapter 3, the data collected will undergo a qualitative content analysis to develop research and finding chapters. Information will be primarily descriptive and use a number of real-world case examples to illustrate and clarify key issues. An extensive documentation review will be the principal method of gathering information, and will be supplemented with a number of interviews.

1.4.1 Methodology

1.4.1.1 Documentation Review

For a large part of the research, the primary method of data collection will involve a thorough documentation review, which will include books, journals, whitepapers, newspapers and press releases. E-Research from websites and databases will also be included. To allow a more effective analysis to be conducted, the information collected will be categorised and sorted into themes such as RFID, barcodes, SCM and the EPC standard. As applications of RFID technology for use in SCM are relatively new, literature is more readily available and current in such publications. In

addition, there is no industry standard in place so the best way to obtain information relating to standards is through current documentation. Thick descriptions, embedded quotes and mini-cases will be used to provide “factual” evidence.

1.4.1.2 Interviews

A number of semi-structured interviews will be performed to supplement and further validate the extensive documentation review. This will allow for comparisons in the use of barcodes and RFID in different SCM environments to be carried out. Interviews will be held with employees working at a strategic level within companies using barcodes and/ or RFID for SCM. Equipment and solution vendors will also be interviewed as they can provide information on a broad range of past deployments, new products and applications, as well as information on future tends in the SCM auto-ID industry. Interviews will focus on deriving background information of the barcode or RFID deployments and discovering the advantages and disadvantages of each technology so that the data can be effectively analysed.

1.5 Conclusion

There remains a clear gap in literature dealing with SCM, as was identified in this proposal. This research will fill the void and clearly identify the advantages and disadvantages of barcodes and RFID in SCM, which will be in chapters 4 and 5. A robust research design has been outlined that will provide the required information to derive a conclusion.

1.5.1 Limitations

Due to the scope of this thesis, there are a number of research limitations. These limitations lead to areas in which further research can be conducted and may be suitable for other theses. The scope will result in a lack of quantitative data to prove specific findings such as how many companies are using RFID in SCM or exact cost savings realised by corporations. The thesis will not be investigating issues such as society’s privacy concerns. Privacy advocates ensure that privacy related RFID issues remain at the forefront of the industry. The concerns of these groups need reviewing to decipher the extent to which privacy regulations may limit the use of RFID.

Chapter 2 - Literature Review

2.1 Introduction

This literature review will satisfy the first objective as stated in section 1.2, which is to review literature on eBusiness with a view to identifying cases in the use of barcode and radio frequency identification (RFID) technology in supply chain management (SCM). The literature review will employ a topical organisation with previous research divided into segments that represent categories or conceptual subsets relating to the thesis.[17] The review will consist of the following four distinct sections:

1. Barcodes
2. Radio Frequency Identification
3. Supply Chain Management
4. The Electronic Product Code (EPC) Standard

This chapter will summarise and critically analyse previous research associated with the thesis. Availability of past works relating to the core elements of this research is scant. Initially the fundamental concepts of barcodes and RFID will be explored, as these technologies form the core foundation of the research. Works covering the importance of SCM will be examined and the concepts identified will be supplemented with examples describing the role barcodes and RFID play in SCM efficiency. Lastly, there will be a review of literature surrounding the requirement of a global standard such as that offered by the EPC network. The literature review will attempt to identify a gap in the previous research, thereby justifying the need for further research to identify the advantages and disadvantages of barcodes and RFID in SCM.

[17] Anderson, T. & Kanuka, H. 2003. E-research: methods, strategies, and issues, Allyn and Bacon, Boston.

2.2 Barcodes

2.2.1 Introduction and History

Barcodes are "printed horizontal strips of vertical bars used for identifying specific items".[18] A "scanning device reads the barcode by moving a beam across the symbol".[19] The first barcode system was developed around the 1940s and 1950s, since then people have become very accustomed to their use, through common applications such as in retail and grocery markets.[20] The thesis will identify the advantages and disadvantages of barcode technology and outline how traditionally, it has been one of the primary auto-ID technologies used to streamline SCM procedures.

There is a large array of works, such as *Behind Bars*[21], that delve into the history and development of barcodes. While this work provides a descriptive view of barcodes, it fails to critically analyse their use. Similarly, Collins and Whipple in *Using Bar Code: Why it's taking over*[22], offer a concise history of barcodes along with examining the typical components that make up a barcode system. Unfortunately, Collins & Whipple only provide a very short section on RFID and omit the inclusion of a comparison section. Again, a work by Palmer[23] also identifies the typical elements of a barcode system and related concepts. Although this work provides a sound review of barcodes, it too, fails to critically compare barcodes with other technologies.

2.2.2 Barcode Standards

As with the history of barcodes, most works provide, to some degree, background information regarding the development of barcode standards. While most sources examine a number of standards, there is a common facet among all works in that they discuss the importance of the UPC (Universal Product Code) standard. One work in

[18] Library of Automation, loc. cit.
[19] Grieco, P. T, et. al. 1989. *Behind Bars: bar coding principles and applications*, PT Publications, Florida. p. 9.
[20] Granneman, S. 2003. *RFID Chips Are Here.* The Register. [Online]. <URL: http://www.theregister.co.uk/content/archive/31461.html> Last accessed 21/3/2004.
[21] Grieco, P. T, et. al., op. cit.
[22] Collins, D. J. & Whipple, N. N. loc. cit.
[23] Palmer, R. C. 1995. *The Bar Code Book- Reading, Printing and Specification of Bar Code Symbols*, Helmers Publishing Inc., New Hampshire.

particular by Brown[24] provides a thorough insight into the development of the UPC standard, including its formation and in depth historical aspects. Regrettably, this book does not explore the use of barcodes or their application to SCM, as it solely covers the UPC standard for barcodes and related issues. Most works on barcodes include some background information regarding the importance and development of the UPC and the Uniform Code Council (UCC).

Palmer offers a broad range of technical information on barcode standards and symbologies. A symbology is "the term used to describe how information is encoded into the physical attributes of the bars and spaces" [25], and, as such, it is of significant importance to barcodes. The scope of this thesis does not include such technical considerations. Other works discuss the ongoing improvements to barcode standards such as two-dimensional (2D) symbologies. In the article *EAN/UCC create new item marking symbologies*[26], a new family of linear barcodes, reduced space symbology (RSS), is explained. This symbology "will allow for the co-existence of symbologies already being used and can be supported by [existing barcode equipment]".[27] The article has a limited scope, only discussing composite symbologies.

2.2.3 Barcode applications

Barcode technology has been used for decades and during this time has proved itself as a reliable performer when supporting SCM.[28] Testament to this is the versatility in which the technology can be adapted to suit specific applications. There is a plethora of case studies which examine the role of barcodes within a particular SCM scenario such as *Auto Group hits high notes with new inventory management system*[29] and *RF cuts processing time for Lexus car and parts deliveries*[30]. The articles provide a snapshot of specific barcode implementations and, as with most works of this time, both case studies provide an analysis of how barcode technology is helping the

[24] Brown, S. A. loc. cit.
[25] Palmer, R., op. cit., p 15.
[26] Moore, B. & Albright, B. 1998. *EAN/UCC create new item marking symbologies*. August/September. Automatic I.D. News Asia. pp. 24 – 25.
[27] ibid., p 24.
[28] Meyers, R. 2000. *The ten commandments of bar coding*. Frontline Solutions, August. pp. A5 - A22.
[29] Automatic I.D. News Asia. 1998. *Alto Group hits high notes with new inventory management system*. March/April. pp. 26 - 28.
[30] Automatic I.D. News Asia. 1998. *RF cuts processing time for Lexus car and parts deliveries*. August/September. pp. 30 – 34.

company improve their SCM processes. The articles review most aspects and processes of the new system and outline the benefits realised post implementation. RFID technology has had a number of substantial technology advancements of late and as both of these articles were written in 1998, alternative RFID technology has not been compared in the case studies, which would have made the case studies much more applicable to this thesis.

The majority of works which provide information about barcodes offer some examples of their applications within a vertical sector. There is significant level of similar findings among works which offer examples of barcode applications. For example Grieco[31], Palmer[32], Collins and Whipple[33], Cohen[34] and Zebra Technologies[35] all present similar example applications in cases like hospitals and health care, retail, library and distribution. In addition to this, most of these examples do not address the importance of barcodes in SCM.

2.2.4 The Future of Barcodes

The work of Cohen in *Automatic Identification and Data Collection Systems*[36] explores current trends in a range of automatic identification and data collection technologies. No formal methodology is used; instead, Cohen uses an informal case study approach when identifying these technologies. Cohen goes on to explore future trends and developments in the industry. Like a number of the reviewed works, Cohen has not given all technologies equal weight in his work, opting to focus on barcode technology.

An article by Vernon[37] explores new developments in barcode applications and emphasises that further developments in barcode technology are continually being

[31] Grieco, P. T, et. al., op. cit., pp. 135 – 168.
[32] Palmer, R., op. cit., pp. 225 – 240.
[33] Collins, D. J. & Whipple, N. N., op. cit., pp. 12 – 16.
[34] Cohen, J. 1994. *Automatic Identification and Data Collection Systems*, McGraw-Hill Book Company, London.
[35] Zebra Technologies. 2004. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/WP13455LfoodService.pdf> Last accessed: 22/3/2004.
[36] Cohen, loc. cit.
[37] Vernon, M. 2003. *Don't count out barcodes just yet: Teaching an old technology new tricks*. [Online]. <URL: http://msnbc.msn.com/id/3606439/> Last accessed: 2/4/2004. p 1 – 3.

made. Although the article is simply descriptive and does not make use of any formal research methods, it does offer some modern barcode concepts. It notes that there is "no shortage of innovative new applications for barcodes" and that "useful development in the technology [barcodes] continue to be made". It goes on to discuss specific new barcode developments such as 2D barcodes. "Unlike standard barcodes, which depend on links to a larger database, 2D barcodes contain a kind of mini-database themselves, which includes information on the product and can be encrypted". [38] Another useful feature of this technology is that even if the barcode is partially damaged, information can still be gathered. A small section notes that many systems now allow for barcode and RFID technology to be combined, alluding to the concept of the integration and convergence of the two technologies, which will be covered in section 2.3.4.1.

2.2.5 Summary Conclusion of Barcodes

There lies a common theme and structure to most of these works, which is that they all cover elementary ground and follow a similar structure. Typically, they cover barcode definitions and provide a brief history, followed by describing parts that make up a barcode system such as printers and readers. Finally, they cover common past business applications. Many of these sources neglect to delve into exploring what the future of barcode technology may yield. The few articles that attempt to explore the future of barcodes, typically, do not utilise a rigorous methodology. Several works explore alternative technologies such as RFID, however rarely is RFID given an equal weighting to that of barcodes. In addition to this, there is a tendency to avoid the critical analysis of barcodes and their use within SCM.

2.3 Radio Frequency Identification

2.3.1 Introduction and History

RFID is a "generic term for technologies that use radio waves to automatically identify individual items. There are several methods of identifying objects using RFID, but the most common is to store a serial number that identifies a product, and

[38] Vernon, loc. cit.

perhaps other information, on a microchip that is attached to an antenna".[39] An essential aspect of any functional RFID system are 'interrogators' or 'readers' which are used to read or write to RFID tags.[40] The British military developed RFID technology during World War II as part of their *Identify: Friend or Foe* system. The program involved an RFID transponder being placed on all British aircraft allowing the British to identify if returning planes were friendly or enemies. A variation of this system is still being used today for aviation traffic control.[41]

The Savi Technologies whitepaper *Active and Passive RFID: Two Distinct, But Complementary, Technologies for Real-Time Supply Chain Visibility*[42], makes the important distinction that RFID encompasses two fundamentally different technologies, active and passive RFID tags. The whitepaper highlights how active and passive RFID technologies are complementary to each other in improving real-time SCM visibility and efficiency. The comprehensive definitions of both of these technologies and their individual role in SCM will be important when identifying how they suit SCM systems. The article does not use a formal methodology and it should be remembered that an industry RFID solution provider, Savi Technologies funded the whitepaper.

2.3.2 Radio Frequency Identification Standards and Regulations

It should be made clear that when discussing RFID standards there are two fundamental differences. First, there are standards and regulations for the physical operating environment of RFID in terms of frequency ranges. This issue is of a broad nature, involving many countries, international standards organisations and telecommunications authorities. The scope of this thesis does not allow for the inclusion of the regulatory issues of RFID frequencies. Second, there are standards for the use of RFID technology, which allow the identification of individual products such as the EPC standard which will be covered in section 2.5. An article by

[39] RFID Journal. 2004. *Frequently Asked Questions*. [Online]. <URL: http://www.rfidjournal.com/article/articleview/anchor#002> Last accessed: 1/4/2004.
[40] Finkenzeller, K. loc. cit.
[41] Grubb, S., et. al. *Radio Frequency Identification*. Purdue University. [Online]. <URL: http://www.tech.purdue.edu/graduate/courses/Tech621aw/Rfid.pdf> Last accessed: 2/4/2004.
[42] Savi Technology. loc. cit.

McNermy stresses that a "regulatory environment will push RFID adoption".[43] Although the article does not adequately cover this theme, it does put in context, the importance of standards and regulations in driving RFID uptake.

Finkenzeller's book provides a thorough review of technical aspects concerning frequency ranges and radio licensing regulations. Most of this information relates specifically to the technical operating frequency ranges of RFID technology, which may prove to be one of the significant limiting factors affecting uptake and the effective use of RFID technology on a global scale. Regrettably, Finkenzeller's methods offer only a small amount of space to describe a few sample standalone applications of RFID, with no relation to wider SCM processes, an area with which this thesis is concerned.[44]

Other papers such as *Global Markets and Applications for Radio Frequency Identification*, offer an alternate approach to analysing RFID regulations. This industry whitepaper recognises that the "need to use the radio spectrum, coupled with the requirement that RFID systems comply with the various spectrum management plans of different countries, is one of the biggest limitations to the success of the RFID industry". It recognises that typically, radio spectrums are managed by individual nations and most countries treat the radio spectrum as a "natural resource". The paper is rather useful and succinctly discusses several other technical aspects, although there is no formal methodology used in this primarily descriptive work.[45] If countries fail to allocate sufficient radio frequency spectrum for the use of RFID, or implement regulations that are substantially different to other countries, then the subsequent global uptake of RFID will be significantly hampered. Ultimately, this will primarily affect the use of RFID within SCM as many large multinational companies have global supply chains that cross many boarders.

[43] McNermey, G. 2003. *Companies are struggling with where to start using RFID to enhance their supply chains*. AMR Research. [Online]. Computer Weekly <URL: http://www.computerweekly.com/Article119659.htm>. Last accessed 7/3/2004.
[44] Finkenzeller, loc. cit.
[45] Krebs, K. & Michael L. 2001. *Global Markets and Applications for Radio Frequency Identification*. Venture Development Corporation. Natick Massachusetts. [Online]. <URL: http://www.rfidusa.com/pdf/2001-rfid-whitepaper.pdf> Last accessed 3/4/2004. pp. 5 – 6.

2.3.2.1 The Electronic Product Code Standard

The EPC standard is similar to the barcodes UPC symbology. The primary difference is the EPC standard's ability to assign a unique number to each individual item allowing it to differentiate between the 24th packet of chocolate from the 1024th. An EPC contains 96 bits of information, including a serial number, "an EPC acts – like a URL - as a reference to a document", which exists on a network.[46] The UPC symbology on the other hand is the symbology used by barcodes throughout the American grocery industry. The UPC symbology was developed primarily for point-of-sale price look-up and does not allow individual products to be uniquely identified.[47]

One of the forces hindering the adoption of RFID in supply chain applications is the lack of prevailing standards, as noted by Tompkins Associates.[48] Similarly, McNerney points out the importance of the EPC standard, noting that a ratified "regulatory environment will push RFID adoption".[49] Although neither of these papers give much space to the EPC standard they do offer some informative comparisons between the UPC symbology and the EPC standard. There is a need for the EPC standard within SCM, as identified by VeriSign, it "addresses real-world challenges by enabling the automatic dissemination and discovery of real-time, accurate, and on-demand product information for all parties in the supply chain".[50] A common facet among articles covering the EPC standard is that they all agree that the need for the EPC standard is paramount for the successful adoption of RFID technology within SCM.

2.3.3 Radio Frequency Identification Applications

There is a plethora of works that cover RFID applications with most providing a brief overview of common applications. For example, AIM Global offers some generic solutions, identifying cases for RFID in transport and distribution, industrial, security

[46] Mullin, E. 2002. *Electronic Product Code*. Baseline, Ziff Davis Media Inc. [Online] <URL: http://www.baselinemag.com/article2/0,3959,655991,00.asp> Last accessed 16/3/2004.
[47] Collins, J. & Whipple, N., op. cit., pp. 26 – 28.
[48] Singer, T. 2003. *Understanding RFID – A Practical Guide for Supply Chain Professionals.* Tompkins Associates. [Online]. <URL: http://www.tompkinsinc.com/publications/monograph/monographList/WP-15.PDF> Last accessed 23/3/2003. p. 4.
[49] McNerney, G., loc. cit.
[50] VeriSign. 2004. *The EPC Network: Enhancing the Supply Chain*. 'VeriSign White Paper'. [Online]. <URL: http://www.verisign.com/nds/directory/epc/epc_whitepaper.pdf> Last accessed 1/3/2004. p. 1.

and access control, and animal control. This article is very concise and unfortunately does not investigate these examples more thoroughly.[51] Zebra Technologies offer a similar overview of RFID applications, providing examples in areas such as logistics, shipping and receiving, warehousing, pharmaceutical industries, security and health care. As with AIM Global's article, this work does not provide in-depth examples and lacks the use of a formal methodology. An article by Granneman titled *RFID Chips Are Here* provides some insightful, but rather brief, applications with some valuable statistics; however there is too much consideration given to consumer privacy concerns for these examples to be of much value.[52]

Some works provide more comprehensive examples of RFID applications, such as those offered by Gerdeman in *Radio Frequency Identification Application 2000*.[53] A large portion of the book is devoted to offering an extensive range of industrial applications. Gerdeman does not compare these applications with alternative barcode technology and more importantly does not relate his examples to SCM. On a similar note, Finkenzeller presents a number of detailed example applications, but as with Gerdeman these examples are not compared to barcodes and are not associated with SCM.[54]

One publication which is atypical of most books and articles on RFID is the work of Geers et al. in *Electronic Identification, Monitoring and Tracking of Animals*. Rather than opting to provide a broader insight into RFID technology, Geers focuses specifically on providing in-depth information on the application of RFID technology in the electronic identification, monitoring and tracking of animals and is considered a landmark study. The technical nature of the study goes beyond the realms of this thesis. Geer does not explore alternative technologies such as barcodes, most likely due to the inherent line-of-sight limitations that are inbuilt in barcodes. The scope of the work is quite limited in that Geers devotes the vast majority of the work to the

[51] Aim Global. *RFID – Common Applications*. Association for Automatic Identification and Mobility. [Online]. <URL: http://www.aimglobal.org/common_applications_rfid.asp> Last accessed: 15/9/2004.
[52] Granneman, loc. cit.
[53] Gerdeman, J. D. loc. cit.
[54] Finkenzeller, k., op. cit.

tracking of animals; however, the work does discuss the possibility of using the technology for the tracking of humans.[55]

On a similar note, Crowe[56] reports on a specific trial being conducted in Australia where 250 000 sheep have been tagged with RFID transponders. This article demonstrates the versatility of RFID technology and adds to the ever growing number of potential applications for RFID technology. This article initially provides a descriptive summary of this RFID implementation, before it moves on to warn that such "new projects [involve] considerable risk". On first review it may seem that this article goes against the general consensus of most works, saying that "RFID cannot change your supply chain", "what RFID gives you is a piece of unique, dynamic information that is produced as a by-product of doing business, so you don't have to go looking for the information".[57] These quotes point out that to gain the most potential from such technology, SCM systems need to be configured to fully utilise the new detailed information, which was traditionally unavailable using barcode systems.

Applications of RFID will be a vital part of the thesis and will be included in the form of mini real-world cases, as it is important to examine actual applications when ascertaining the pros and cons of the technology. While many of the works provide example applications, there is a clear gap in previous research when it comes to providing a comparative analysis of RFID and barcode technologies in SCM. It is interesting to note the similarities among the works on RFID as cited above. Aside from Granneman's[58] downsides of RFID due to privacy issues, all of the applications provided a similar positive outlook for the future of RFID. In addition, most works favour the examination of a number of applications rather than focusing on a specific application, as done by Geers[59].

[55] Geers, R. 1997. Electronic Identification, Monitoring and Tracking of Animals. CAB International, United Kingdom.
[56] Crowe, D. 18/3/2004. *Tag Technology coming of age, and sheep are leading the way*. Special Reports – The New Supply Chain. The Australian Financial Review. p 8.
[57] ibid.
[58] Granneman, loc. cit.
[59] Geers, R., loc. cit.

There are many differences between barcode and RFID technology; however one fundamental difference is that "unlike bar codes, the [RFID] technology allows for tracking of individual items". Lawson provides some limited comparisons between RFID and barcodes and citing that "there will be plenty of advantages in having radio chips in items at all levels to track them through the supply chain". The article uses comments from many professionals in the SCM industry, adding to its creditability. An example of this would be from the leader of the supply chain management group at Deloitte, Brett Campbell, who says, "one major advantage that RFID systems have over bar codes is that the chips do not have to be near the radio transponder to be tracked".[60] This article is quite applicable when examining some of the perceived advantages of RFID, however the article is brief and aside from some limited input from industry professionals, no methodology, or evidence is provided.

Some works provide partial focus on exploring the specific areas where RFID will deliver its greatest advantages to SCM. *Adaptive Supply Chain Networks* by SAP is one such article. It cites benefits such as the fact that tags can "survive in harsh environments such as extreme temperatures, moisture, and rough handling". Unfortunately, this whitepaper does not provide an in-depth analysis, opting to only list several such benefits.[61] The Savi Technology whitepaper, *Active and Passive RFID: Two Distinct, But Complementary, Technologies for Real-Time Supply Chain Visibility* replicates the offerings of SAP's paper. It offers a limited list of how RFID may benefit SCM through enhancing supply chain visibility. Again, this article also neglects to provide depth with its examples and lacks the use of a sound methodology.[62]

2.3.4 The Future of RFID

One of the key parties driving the uptake of RFID is Wal-Mart (a major U.S. retailer) who has mandated that its suppliers will be required to use RFID by 2006, with many other large retailers following this lead.[63] Papers offering in-depth studies attempting

[60] Lawson, M., loc. cit.
[61] SAP White Paper, op. cit., p 13.
[62] Savi Technology., loc. cit.
[63] Leyden, J. 2004. *European retailers have the hots for RFID*. The Register. [Online]. <URL: http://www.theregister.co.uk/content/53/35214.html> Last accessed 21/3/2004.

to forecast the adoption cycle and the future of RFID are not readily available. The main cause of this is due to the fact that uptake of RFID technology for use in improving SCM has only recently been considered as an alternative to barcodes. Most articles discussing RFID offer their predictions using brief example applications. *RFID: The Next Generation of AIDC* by Zebra Technologies which offers examples of possible applications of RFID technology such as to assist in the management of Alzheimer's patients. The article gives little space to such example cases and does not use any formal methodology to analyse these examples.

A thesis titled *Humancentric Applications of RFID: The Current State of Development*, by Amelia Masters examines the current applications associated with RFID implants in humans. It attempts to "bridge the gap between existing technical knowledge and [speculates] future uses".[64] Another article by Michael and Masters is restricted by its scope as it specifically explores applications of human transponder implants in mobile commerce.[65] Both of these works primarily employ descriptive methods and are quite informative. Nevertheless, neither paper explores alternative technologies, which would have made them much more applicable to this research.

One study does focus its attention on questioning the future of the RFID industry and tries to specifically outline its role in the future of retail supply chains. The article, *Industry Developments and Models: The RFID Ecosystem for the Retail Supply Chain* by Christopher Boone notes that RFID still has some hurdles to overcome before its full benefits can be realised. It attempts to differentiate between the promise and reality of RFID in the supply chain, admitting that the question is not if RFID will be implemented, rather when and how it will be used. What makes this article unique is that it provides a future outlook, likening the stages of RFID deployment to that of a Matrioshka doll, anticipating five stages of deployment. Lastly, it offers a forecast timeline for the uptake of RFID technology in the retail supply chain providing specific dates. Despite this, the work unfortunately does not analyse how the uptake will affect current barcode technology. No mention is provided as to the use of a

[64] Masters, A. 2003. *Humancentric Applications of RFID: The Current State of Development*. Bachelor Honours Thesis, University of Wollongong.
[65] Michael, K & Masters, A. 2004. *Applications of Human Transponder Implants in Mobile Commerce*. University of Wollongong.

formal methodology and as there is no past research, which strongly supports this view; questions may therefore be raised over its credibility.[66]

2.3.4.1 The Co-existence of RFID and Barcodes

The concept of a co-existence between RFID and barcodes is echoed in a number of works, as offered by Michael[67] and Zebra Technologies[68]. The work of Michael uses a robust methodology; however the study examines a broader range of technologies as opposed to the comparison of just barcodes and RFID and does not explore how these technologies can streamline SCM processes. Zebra's whitepaper discusses the relationship that could be shared between RFID and barcodes within a number of applications. A brief mention is made about the need for a global standard such as the EPC Standard. The review of this article needs to be particularly critical as Zebra Technologies implement RFID and barcode solutions to industries so their review may be biased. These ideas are supported by the work of Swartz who believes that "we'll evolve from a 'coexistence' model to one that leverages the many converging opportunities around the intersections and in the gaps between those technologies".[69] The article goes on to discuss a number of automatic identification technologies, acknowledging there are a number of these technologies "overlap". Unfortunately the article only briefly discusses these technologies, lacking the depth to critically analyse them and their potential application in SCM.

2.3.5 Summary Conclusion of RFID

Many of the articles reviewed provide similar, but innovative concepts for applying RFID technology but fail to investigate these ideas in relation to the "bigger picture" of SCM. Such articles often opt to promote end solutions, which is due to a large number being industry funded. Each article provides useful information, however there is a lack of research comparing RFID with barcodes in terms of SCM.

[66] Boone, C. 2003. *Industry Developments and Models: The RFID Ecosystem for the Retail Supply Chain*. IDC, Framingham.
[67] K. Michael. loc. cit.
[68] Zebra Technologies. loc. cit.
[69] Swartz, J. 1999, *The growing 'MAGIC' of automatic identification*, IEEE Robotics & Automation Magazine, pp. 20-22, 56.

2.4 Supply Chain Management

SCM is the "management and control of all materials and information in the logistics process from acquisition of raw materials to delivery to end user".[70] The continual improvement of SCM has been a key focus in many organisations for some time now and has lead to significant cost savings. The competitive nature of organisations drives the demand for new technology to pave the way for improvements to SCM.

2.4.1 The Importance of Supply Chain Management in the Modern Business Environment

There is a multitude of forces simultaneously placing new strains on companies. Nine out of ten companies rate SCM and control as the key to their company's future success, even survival.[71] With competition increasing throughout all facets of modern day business, the supply chain is coming under increasing scrutiny, and is proving itself as a way to cut costs and gain a competitive edge.[72] There is a shift in the traditional information economy, which is being brought about through the advent of the Internet, which brings with it the term 'hyperarchy' whereby there is no longer a trade off between reach and richness when exchanging information. This has ultimately resulted in the deconstruction of traditional value chains, removing the once formidable barriers to entry.[73] This shift in the modern day information economy has driven businesses to seamlessly adapt to ever changing business demands through advanced supply chains.

A SAP whitepaper coins the term 'adaptive supply chain networks', whereby supply chain networks have built in redundancies providing the ability to withstand unpredictable shocks, such as terror attacks. The paper says that "adaptive supply chain networks [possess] the flexibility to continually morph and respond to the environment in real-time without compromising on operation and financial efficiencies".[74] The article goes on to identify that "with the Internet, consumers can

[70] CSX World Terminals, LLC, loc.cit.
[71] Softchain. loc. cit.
[72] Lawson, M. 2004. *Technology is reshaping the industry*. Special Reports – The New Supply Chain. The Australian Financial Review. pp. 2 – 3.
[73] Evans, P. & Wurster T. 1997. *Strategy And The New Economics of Information*. Harvard Business Review, 75 (Sept – Oct): pp. 70 – 82.
[74] SAP White Paper, op. cit., p 5.

compare prices, shop the globe, and get knowledge for next to nothing. Margins are bound to fall".[75] It is also noted that due to these increasing pressures, business are being forced to build supply networks that are far more responsive. Further pressures on businesses such as shrinking capital availability and information ubiquity are identified by the whitepaper, which are driving changes and increasing the importance of SCM efficiency. While this paper further explores other pressures on business that is increasing the importance of SCM efficiency and briefly examines how RFID may aid this process, it does not examine the role barcodes currently play in the process. It is also of a descriptive nature, using no formal methodologies and as an industry player has published it, promoting SAP solutions at the end of the paper, readers should be critical when reviewing this paper's findings.

There is replication of the common themes raised by most papers, as found in *Supply Chain Management Systems: State Of The Art And Vision*, which notes that information technology has brought with it, both challenges and opportunities to SCM, making its importance grow at an even faster pace. It also recognises that many companies are realising "it has become clear that a supply chain that flows information and material best can be a significant differentiator, the competitive winner".[76] Adding to the significance of this paper is that it supports most of the other papers and has been written by academics. It also lists modern day drivers that increasing the importance of SCM. Regrettably, the paper is primarily concerned with SCM, and does not delve into covering the importance of specific technologies as offered by barcodes and RFID.

Another paper *Focus on the Supply Chain: Applying Auto-ID within the Distribution Center*, studies the goal of SCM reaching levels of the upmost efficiency within a business. The paper provides some useful cross analysis between new technologies and the impact barcodes have had since their inception. Unfortunately, the whitepaper limits the study to within distribution centres. In addition to this, the paper does not provide much depth on how alternative technology can be implemented and mainly

[75] SAP White Paper, op. cit., pp. 6 – 7.
[76] Wu, J., et. al. 2000. *Supply Chain Management Systems: State Of The Art And Vision*. Department of Mechanical and Manufacturing Engineering, The University of Calgary, Calgary Canada.

employs the use of a financial comparison between two example companies in its study.[77]

Burnell provides excellent examples that demonstrate how important proficient SCM can be for larger businesses through using small examples analysed in monetary terms. He notes for example "Hong Kong's export industries could save $9.2 billions annually and the consumer goods industry could save $5 billion if SCM programs were fully utilised".[78] The article also outlines the components of successful SCM systems and provides small case study examples where necessary.

Most works support the common belief of the importance of SCM, especially in modern day business. While most articles are backed by industry SCM solution providers, they all offer similar ideas when describing the importance of SCM. Many offer alternating concepts and solutions as often the papers push their sponsors products and services.

2.4.2 Problems with Supply Chain Management

The paper *Automating Supply-Chain Management* cites problems with SCM, ranging from shortages in stock, excessive finished good inventories, underutilised plant capacity, unnecessary warehousing costs and inefficient transportation of supplies and finished goods. In addition, the paper states that a recent study has found that "companies lose between 9% and 20% of their value over a six-month period due to supply chain problems".[79] Aside from this brief section, the paper becomes somewhat technical, discussing a complex methodology. It fails to identify real world causes for SCM problems. Softchain's whitepaper, *Improving Extended Supply Chain Performance* identifies important aspects of SCM and the addresses the challenges facing organisations in these areas. This paper's purpose is clearly aimed to promote

[77] Keith, A. et. al. 2002. *Focus on the Supply Chain: Applying Auto-ID within the Distribution Center*. IBM Business Consulting Services. Auto-ID Center, Massachusetts Institute of Technology.
[78] Burnell, J. 1998. *Technology Tames Logistics – Matching information flow to material flow is key to benefits in logistics and supply chain management programs*. May/June, Automatic I.D. News Asia.
[79] Huhns, M., Stephens, L & Ivezic, N. 2002. *Automating Supply-Chain Management*. Available ACM Press. Last accessed: 1/4/2004.

Softchain's SCM software, which should be kept in mind and taken into consideration when reviewing it.[80]

Some works examine a specific period of time, such as the paper by KPMG Consulting, *Lessons in Supply Chain Management from 2001* which explores how and why SCM networks failed to predict the dot-com bust. The article provides a thorough overview and uses descriptive approach and supports its findings with quantitative data where required. The reasons why SCM systems failed to predict this downturn and provide adequate lead times, which would have allowed adjustments to be made to compensate the downturn in demand, are outlined and explored. The article cites the need for an "increase [in] supply chain planning sophistication".[81] While the article is insightful, it lacks the scope to link the use of technology as offered by barcodes and RFID as a means to aid in the resolution such issues.

2.4.3 Technology's Role in Improving Supply Chain Management Efficiency

Lawson's statement "Technology is making it much easier to control the [supply] chain" echoes the thoughts raised by most papers in discussing this field.[82] Similarly, an article by Palagyi supports the use of information provided by information technology; it further supports this theme by saying "information technology is a potent tool in supply chain improvement".[83] The work lists steps required in successfully developing an effective SCM solution, however at no stage does it offer specific technical solutions as offered by barcodes or RFID.

Some articles identify the need for technology to support SCM procedures, but lack depth when investigating the inner workings of these procedures. A good example of this is the work of Kumar in *Technology for Supporting Supply Chain Management*, where the author does a good job identifying the need for technology to support the supply chain, but skirts around the issue of how this will be done. The paper says, "in a constantly evolving, complex world of local and global supply chains appropriate

[80] Softchain, loc. cit.
[81] KPMG Consulting. 2001. *Lessons in Supply Chain Management From 2001: The Imperfect Crime*. 'Supply Chain White Paper'. p 10.
[82] Lawson, M., loc cit.
[83] Palagyi, S. 1999. *Six steps toward supply chain optimization*. June, Automatic ID News Asia.

use of ICT [information and communication technology] is absolutely vital to achieving value and cost advantages in the supply chain", however aside from some discussions of technology in terms of software there is no mention of physical technologies such as barcodes and RFID in supporting SCM.[84]

An application whitepaper produced by Zebra Technologies, *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*, does an excellent job of specifically highlighting the importance of barcodes and RFID technology in the foodservice industry. Although the paper demonstrates the role that these two technologies can play in aiding SCM, it does not critically analyse and compare these two technologies. In addition to this, the article has a limited scope, which only investigates the combined role of these technologies in the foodservice industry.[85]

2.5 Conclusion

This literature review has examined past research in the ebusiness field with a view to identifying cases in the use of barcode and RFID technology in SCM, and in doing so has satisfied objective 1 as stated in section 1.2.2. Through meeting this objective, the literature review has, also met the requirements of objective 2 as stated in section 1.2.2, which was to identify a gap in past research.

The key elements of the thesis, barcodes, RFID and SCM all have past research. However, while initially there seems to be a plethora of information on barcodes, RFID and SCM, the availability of research papers, particularly those of an academic nature, is rather scant. Past works do cover these themes on an individual level, but lack the critical in-depth analysis of both barcodes and RFID within SCM terms. As the key fields are relatively new concepts, past research is quite current however; most works tend to be industry-funded whitepapers, which often avidly promote end solutions and the implementation of such technologies. Furthermore, most fail to

[84] Kumar, K. 2001. *Technology for Supporting Supply Chain Management*. 'Communication of the ACM', Vol. 44. No. 6. pgs58-61. [Online]. Available ACM Press. <URL: http://doi.acm.org/10.1145/376134.376165> Last accessed 15/3/2004.
[85] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. loc. cit.

utilise robust methodologies that can lead to questionable findings. Consequently, these facts serve to strengthen the necessity of further academic research to identify the advantages and disadvantages of barcodes and RFID in SCM and foretell how this relationship will develop, which is where this thesis will make its contribution.

Chapter 3 - Methodology

3.1 Introduction

This thesis will identify the advantages and disadvantages of barcodes and radio frequency identification (RFID) technologies in supply chain management (SCM) with a view to highlighting the importance and need for a ratified global RFID standard. It will also investigate how the relationship of these two automatic identification (auto-ID) technologies will develop. To effectively carryout this research, a robust underlying methodology is required. The methodology must allow for the objectives of the thesis to be achieved, and as such, these objectives have been listed below:

3.1.1 Research Objectives

1. To review literature on eBusiness with a view to identifying cases in the use of barcode and RFID technology in SCM.
2. Use the outcomes of objective one to identify a gap and a suitable methodology for investigating the advantages and disadvantages of barcodes and RFID in SCM.
3. Explore the advantages and disadvantages of barcodes and RFID in SCM using the methodology developed in objective two, which will utilise a documentation review and interviews of market stakeholders.
4. Identify the drivers for RFID uptake and discuss how the adoption of barcodes and RFID will evolve.

This chapter will identify a suitable methodology for investigating the advantages and disadvantages of barcodes and RFID in SCM and in doing so, will partially satisfy objective two, as listed above.

The preceding literature review outlined the need for further academic research within this area. It identified a significant gap in previous work, with the vast majority of past papers being industry-funded whitepapers, which often failed to utilise robust methodologies. Previous works typically lack the scope to focus specifically on both

barcodes and RFID within the context of SCM. This thesis will offer a different approach to the area, using an original method. In addition to this, most works did not offer equal space to barcodes and RFID, opting to focus on one technology, this thesis will provide each technology equal weighting.

3.2 Research Strategy

The research will employ a qualitative strategy, utilising descriptive research that will explore the advantages of RFID over barcodes in SCM. Descriptive research can be justified, as the scope of this thesis does not allow enough time for the collection of detailed statistics on barcode and RFID implementations, which would also be difficult as there are a limited number of current RFID applications in SCM. In addition to this, the analysis of the likely convergence and co-existence of barcodes and RFID will be based upon an interpretivist approach.[86] Consequently, the research strategy will incorporate an extensive documentation review and interviews. Although there are several auto-ID technologies that could have been examined, barcodes and RFID have been selected as recent debate has been over which technology is most suitable to SCM. Furthermore, these are the two most prominent technologies currentlyused within SCM. A number of factors were outlined in the preceding literature review, which explored drivers behind the recent push for RFID technology.

Diagram 3.1 below, shows the research model of the thesis, illustrating how the documentation review, interviews and representative case examples will be used in the study. The method will offer a whole chapter to both barcodes and RFID, opting to intertwine example cases to form a more thorough study. The structure of the barcode chapter can be seen in diagram 3.1 and is presented with the view of the technology being established. As RFID is at the early stages of its lifecycle, it will be based on technical issues, which are listed in diagram 3.1. Further justification for the structure of chapters 4 and 5 will be provided at the beginning of each chapter. The findings of these initial sections will be analysed through a cross case comparison in the subsequent chapter. SCM systems span beyond the boundaries of vertical business sectors, and thus individual sectors do not need to be specifically addressed, as

[86] Williamson, H. 2002. *Research methods for students, academics and professionals*. 2nd Edition. Quick Print, Wagga Wagga. pp. 30 – 32.

applications tend to be generic. At the SCM level, the examination of barcode and RFID technologies does not require or necessitate a technical and quantitative approach, both of which are beyond the scope of this thesis.

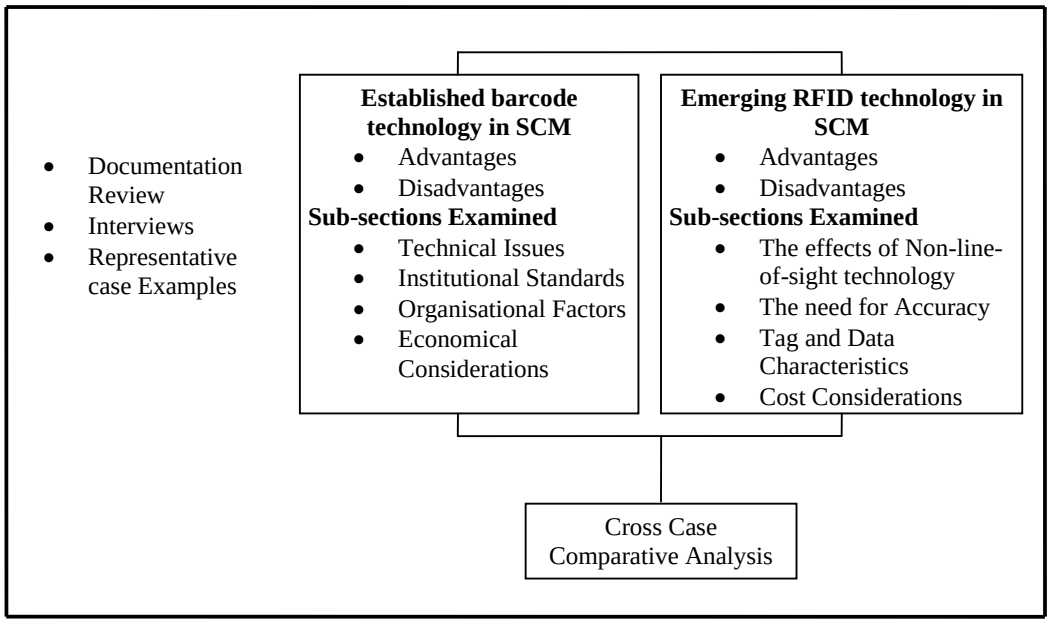


Diagram 3.1: Research Model

3.3 Research Methodology

Information will be acquired using both a thorough documentation review and interviews. Similarities found within both of these sources will demonstrate reliability and deliver more sound conclusions. In addition, real-world case examples will ensure that the findings are applicable to current business issues.

3.3.1 Research Design

The research method's main unit of analysis is auto-ID technology, namely barcodes and RFID, in SCM. As discussed in section 3.2, these two technologies have been selected as they are the two most suited auto-ID technologies for use within SCM applications. Debate over which technology to use is rife, and with recent mandates for such auto-ID adoption by many of the worlds leading retailers, such as Wal-Mart,

organisations need to know which will best aid SCM operations.[87] If suppliers do not adhere to these mandates, they risk loosing their contracts. The sub-unit of analysis will consist of three distinct, yet related bodies, which are standards organisations, technology vendors, and customers or current users of the auto-ID technologies within SCM. The time horizon of the research will take the place of a cross-sectional format with data being gathered as a single process, despite the duration of this phase lasting several months.

3.3.2 Documentation Review

The documentation review will utilise a variety of sources, including books, journals, whitepapers, newspapers and press releases. In addition to this, E-Research from websites and databases will also be included. As highlighted in the literature review, there is a significantly larger number of industry-funded whitepapers in this area. While it is important to be critical of these papers, it is also noteworthy that they offer real and practical application examples and information. Again, reliability and consistency will be achieved through the use of interviews to support findings. The information collected will be categorised and sorted into themes such as RFID, barcodes, SCM and the Electronic Product Code (EPC) standard to allow a better comparative analysis. As applications of RFID technology for use in SCM are relatively new, current literature is more readily available than it is for barcodes. In contrast, barcodes have been widely used for several decades; there is a large volume of information available, although this information may be outdated. In addition, there is no ratified industry standard in place for RFID, so the best way to obtain information relating to standards is through current documentation. Thick descriptions and representative case examples will be used in the case studies to provide "factual" evidence.

3.3.3 Interviews

A number of interviews will be conducted to supplement the information gathered in the documentation review, as outlined in section 3.3.2. Interviews will be conducted

[87] Fontanella, J. 2003. *Wal-Mart Pulls RFID Trigger: The Race Is On.* AMR Research. [Online] <URL: http://www.amrresearch.com/content/DisplayPDF.asp?pmillid=16268&strMasterType=alert> Last accessed: 22/4/2004.

with employees working at a strategic level within companies using barcodes and/ or RFID for SCM. Solution and equipment vendors will also be interviewed as they can provide information on new products and applications, as well as details or previous applications they have developed. The interview will be free flowing using a semi-structured approach, which allows the questioning and discussion greater flexibility, offering the ability to adapt questions throughout the interview.[88] Interviews will focus on deriving background information of the barcode or RFID deployment and discovering the advantages and disadvantages of each technology so that the data can be effectively analysed. At times, there will be reliance on interviews to feed and support the thorough documentation review.

Several barriers exist in regards to the interview structure. These barriers have arisen, as the interviews will be targeting a variety of entities including technology vendors and customers using barcodes and/ or RFID. There is a need for the interview script to be modified to suit these different groups. For this reason, it is not possible to provide a static interview script, however an anticipated initial script for vendors and customers using barcodes or RFID can be found in the subsequent section, 3.3.3.1. This script provides opportunities for lead-off questions and further probing where necessary.

3.3.3.1 Interview Structure

1. General Information
    a. What is the name of the organisation you work for?
    b. What is your position in the organisation?
    c. How long have you been working for this organisation?
    d. In which vertical sector is your organisation?
    e. Which technology does you organisation use, barcodes, RFID or both?
2. Can out please describe any deployments of barcode and RFID technology within your organisation?
3. What were the perceived advantages and disadvantages of implementing barcodes or RFID?

[88] Minichiello, V. Aroni, R. Timewell, E. Alexander, L. 1995. *In-depth Interviewing*, 2nd edition, Longman, Melbourne, p. 65.

4. What have been the actual advantages and disadvantages realised after implementing the technology?
5. What are the anticipated advantages and disadvantages that your organisation expects to bring to fruition from the technology in the future?

3.3.3.2 Justification of Interview Questions

Question 1 is necessary to develop background information on the employee providing the information and the organisation that the information concerns. This will assist the analysis of the information gathered from the interview. Part b and c identifies the length of employment and the position of the person being interviewed which may affect the quality and reliability of information obtained. Part d establishes what vertical sector the organisation is in, whether it is a technology and solution vendor, manufacturer, distribution centre, logistics or retailer.

Question 2 will provide a foundation, to gain background knowledge of all barcode and RFID deployments within or implemented by the organisation. This information will assist in developing lead off questions that probe for further relevant information.

Regardless of the technology being used by the organisation, questions 3, 4 and 5 have a similar structure, so as to not introduce bias towards one technology in the interview. To allow for a more thorough investigation it is important to identify the advantages and disadvantages of each technology, at three stages. First, question 3, before implementation, this will aid in gauging the expectations, which organisations place upon their investment and choice of technology, be it barcodes or RFID. The second stage, question 3, is of significant importance, as it extracts information regarding the actual advantages and disadvantages of the technology, within a real and competitive organisational environment. Third, question 5, the anticipated advantages and disadvantages that the organisation expects to yield from the implementation in the future. Again, this question is aimed at measuring organisational expectations, and attempts to ascertain any trends in the adoption of either auto-ID technology and what future applications may include.

3.4 Data Analysis

The data collected from the documentation review and interviews will be analysed and undergo a qualitative content analysis to identify the advantages and disadvantages realised by organisations using barcodes and RFID in SCM. An investigation of this data will use the following method:

1. Examination of the advantages and disadvantages available to organisations from using barcodes in SCM.
2. Examination of the advantages and disadvantages available to organisations from using RFID in SCM.
3. After completing the two steps above, a comparative analysis of the findings will be conducted to ascertain the advantages realised by companies using RFID over barcodes in SCM.
4. Explore the uptake of barcodes and RFID in SCM, to ascertain drivers for adoption and forecast the future relationship of the two auto-ID technologies.

Several analytical techniques will be employed to more effectively explore and interpret the research findings. These methods will include the use of tables and matrix diagrams to summarise key concepts and characteristics of each technology. It is expected that a table showing the high-level advantages and disadvantages will demonstrate construct validity by identifying that the advantages of RFID typically cater for the disadvantages of barcodes. Tables will also examine the impact of barcodes and RFID at individual phases of the supply chain. Where possible the findings will acknowledge that some advantages and disadvantages may be offered by both auto-ID technologies and will attempt to decipher which technology is most dominant in each area. Furthermore, an adoption fusion curve will be developed to graphically demonstrate the co-existence relationship between barcodes and RFID.

3.5 Conclusion

This thesis will identify the advantages and disadvantages of barcodes and RFID in SCM through examining applications and research on barcodes and RFID. The research will be based upon a qualitative strategy approach. Information will be

gathered from a variety of sources including an extensive documentation review and several interviews with different industry entities. The subsequent chapters will employ the outlined methodology to develop and analyse the issue in a reliable and accurate manner to answer the proposed question.

Chapter 4 - Barcodes: The Mature Auto-ID Technology

An investigation of the barcode's rise to popularity in supply chain management (SCM) and its advantages and disadvantages will be the core theme of this chapter. Barcodes are a mature auto identification technology and have been used in SCM for several decades. As such, the examination of barcode technology will be undertaken with the view of it already being an established technology, with the chapter structured accordingly. The structure of this chapter lends itself to including important technical, institutional standards, organisational and economical factors, which Edquist cited as a way of specifying a system.[89] Consequently, the chapter follows the normal adoption fusion cycle, as first the technology is developed, followed by the evolution of institutional standards, then organisational and economical factors realised by organisations upon implementing barcodes.

4.1 Technical Issues

The road to success for any emerging technology starts with quantifiable advancements in terms of technical attributes. The early technical developments made in barcode technology include their affordability, ease of use, reliability, line-of-sight properties and ongoing developments. This natural technological progression sparks interest from organisations in the technology and is the beginning of its rise to prominence.

4.1.1 Affordability

The simplicity of barcodes is one of their most appealing aspects. Since their inception, typical barcode printing costs have dropped to less than a cent per barcode.[90] As the two core ingredients used to produce a barcode are ink and paper, they will remain relatively inexpensive compared to alternative technologies, such as

[89] Edquist, C. 1997. *Systems of Innovation*. Redwood Books, Great Britain. p. 14.
[90] Thompson, N. 2003. *RFID and barcodes may co-exist for now*. American Printer, Vol.231, Iss. 6; pg. 58. [Online]. Available ProQuest, Document ID: 421309991. Last accessed 11/10/2004.

RFID using silicon chips, for the foreseeable future.[91] Barcode labels can produce significant media savings for organisations, as traditional paper forms are much larger than barcode labels.[92] Brandon notes that for companies with a developed barcode infrastructure, the cost of printing barcodes is almost nothing.[93] As barcode technology has reached state of maturity, it has become much more affordable making it suitable for many small applications. Interview participant two's organisation uses a simple barcode system comprising of a small database, barcode software and several barcode scanners to monitor tool usage and noted that the "system is a very useful and low cost solution".[94]

Continual improvements and the tweaking of barcode technology have ensured that costs continue to decrease. An example of this is the development of linerless barcode labelling. This can decrease media costs by 10-25%, while increasing the number of barcodes on each roll, and creates no leftover waste in the form of discarded label backings, leading to lower production costs per barcode.[95] The cost of barcode equipment has followed this trend with the price of barcode systems dropping such that even small businesses can afford to set up barcode systems.[96]

4.1.2 Usability

Barcode technology's ease of use can be attributed as a significant factor of its success. The technology can easily be generated on the fly and offers a great deal of automation, reducing human interference wherever possible.[97] When the right infrastructure, software and hardware, is in place, the "automation provided by a bar

[91] Swartz, op. cit., p. 22.
[92] Zebra Technologies. 2003. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/13031Lr1-SupplyChainMgmtWP.pdf> Last accessed 1/10/2004. p. 1.
[93] Lai, E. 2004. *RFID Revolution is still just a promise*. American City Business Journals, September. [Online]. Available ProQuest Database, Document ID: 693337261. Last accessed 10/10/2004.
[94] Interview Participant Two, Appendix A2.
[95] Modern Materials Handling. 1996. *Linerless label printing: New technology with proven savings*. Vol.51, Iss. 14; pg. S22, 1 pgs. [Online]. Available ProQuest, Document ID: 10468438. Last accessed 11/10/2004.
[96] Dirks, B. 2003. *Point-of-sale software: A managerial goldmine*. CPA Software News, Shawnee, Vol.13, Iss. 4; pg. 24. [Online]. Available ProQuest, Document ID: 377240051. Last accessed 12/10/2004.
[97] Vernon, loc. cit.

code system greatly simplifies information collection, processing and tracking".[98] Automation has brought companies such as Procter & Gamble double-digit productivity gains.[99]

Gathered information can be easily passed throughout an enterprise and even to an organisation's partners with the use of advanced management systems. Furthermore, the user interaction with barcodes is simple, with many modern systems and scanners providing users with wireless remote data capture and a graphical user interface to assist the training for all users.[100] As barcodes are easy to use, the technology has the ability to be implemented seamlessly into many business applications. This has helped pave the way for a number of other advantages to be realised, such as better inventory management and quality control, both of which will be discussed further in subsequent chapters.

4.1.3 Continual Improvements and Innovations

In preceding chapters, improvements in barcode technology that provided the means to lower costs, such as linerless barcodes, were discussed. However, barcode technology has continued to evolve, reinventing itself to solve and improve a wider array of business issues. Until the 1990s and the advent of powerful computers with large memories, most barcode systems were capable of reading only one symbology, creating a problem when more than one standard was used. Today barcode scanners can typically read a large number of symbologies, coining the term *autodiscrimination*.[101] All of the barcode scanners produced by participant one's employer read all codes where possible.[102]

[98] Zebra Technologies. (No Date). *The Basics of Bar Coding*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/BarcodingBasics200111.pdf> Last accessed 28/9/2004. p. 3.
[99] Varchaver, N. 2004. *Scanning the Globe*. Fortune, New York. Vol.149, Iss. 11; pg. 144, 5 pgs. [Online]. Available ProQuest, Document ID: 643106141. Last accessed 10/10/2004.
[100] Stephenson, C. 1998. *Get a grip with auto ID [Warehouse management systems]*. Canadian Transportation Logistics. Vol.101, Iss. 9; pg. 24. [Online]. Available ProQuest, Document ID: 390771981. Last accessed 12/10/2004.
[101] LaMoreaux, op. cit., pp. 70 – 71.
[102] Interview Participant One, Appendix A1.

Recently Nextel Communications, Motorola and Symbol Technologies announced the first barcode scanner attachment for mobile phones, the PSM20i.[103] [104] This recognises the trend of barcode technology, in particular the growth in popularity of remote data capture scanners using wireless technology. Wal-Mart has deployed over 300 000 wireless barcode scanners.[105] While remote data capture scanners are limited to the range of their wireless network, the range of mobile phone barcode scanner attachments is considerably less limiting. Their range would allow employees to scan items in the supply chain regardless of their location and update the information in real-time, whether they are onsite at a client's warehouse or out in the field.[106]

Vernon acknowledges, "there is no shortage of innovative new applications", citing the development of the "mobi-ticket" system developed by Mobiqa. The system allows customers to purchase tickets online and receive a barcode image on their phone as a multimedia messaging service (MMS). This 'virtual barcode' message can be read with a standard scanner to gain entry to an event, averting the need to mail out tickets. In this way, mobi-ticket helps organisations to manage events and processing costs more efficiently, helping to thwart ticket touts. It also allows vendors to attach promotional material to the 'virtual ticket'.[107] Ongoing developments in symbology standards are also paving the way for new standards that hold substantially more information than more traditional symbologies, which will be discussed in subsequent sections.

4.1.4 Reliability and Accuracy

There is no doubt that barcode scanning is more reliable than manual data collection, yielding vastly higher accuracy rates at high speeds. Accuracy in the supply chain, particularly in the manufacturing stage is paramount.[108] Zebra Technologies claim that read error rates are approximately one error in one million characters or greater than

[103] Vernon, loc. cit.
[104] Symbol Technologies. 2004. *PSM20i Bar Code Scanning Module for Motorola iDEN Phones*. [Online]. <URL: http://www.symbol.com/products/barcode_scanners/barcode_psm20i.html> Last accessed 12/10/2004.
[105] Varchaver, loc. cit.
[106] Symbol Technologies. loc. cit.
[107] Vernon, loc. cit.
[108] Zebra Technologies. 2003. *Bar Coding 101… What You Need to Know*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/11441Lr2-BarCoding101.pdf> Last accessed 29/9/2004. p. 1.

99.99% accuracy.[109] [110] Cohen,[111] Berwin,[112] Reuters,[113] Kevan[114] and interview participant two[115] support the notion of high accuracy read rates for barcodes. In contrast to this, Delta airlines has only achieved read rates of 80% to 85%, however such poor read rates are not common and may be due to environmental constraints.[116]

There is no doubt that trained data entry operators using manual key entry are less accurate and much slower than barcode scanning, making approximately one error for every 300 characters entered.[117] [118] Singer notes that although barcode accuracy rates are near perfect, they typically have one weakness in that they require operators to perform the scan, which can often lead to human mistakes.[119] However, the automation of barcode systems can serve to reduce human error, a topic that will be discussed is later sections.

With many barcodes being manually readable, they hold a distinct advantage over alternative technologies such as RFID. This is a feature San Francisco International Airport found important when barcoding luggage. Should a scanner be unable to read a barcode, the barcode contains enough printed information to allow airport staff to manually route the luggage.[120] An organisation using barcodes to monitor the use of tools found that barcodes would often come back damaged. To counter this problem, the organisation engraved the barcode number into each tool so the information could be read manually should the barcode was damaged. This allows the operator to correctly identify the tool and replace the damaged barcode.[121] Such a unique benefit

[109] Zebra Technologies. *The Basics of Bar Coding*. op. cit., p. 2.
[110] Zebra Technologies. 2002. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/ROI_Mail_whitepaper.pdf> Last accessed 1/10/2004. p. 1.
[111] Cohen, op. cit., p. 21.
[112] Brewin, loc. cit.
[113] Reuters. 2004. *Wired News: Wal-Mart, DOD Forcing RFID*. [Online]. <URL: www.wired.com/news/print/0,1294,61059,00.html> Last accessed 18/9/04.
[114] Kevan, T. 2004. *Improving Warehouse Picking Operations*. Frontline Solutions. [Online]. Available ProQuest, Document ID: 639486161. Last accessed 11/10/2004.
[115] Interview Participant Two, Appendix A2.
[116] Brewin, loc. cit.
[117] Zebra Technologies. *The Basics of Bar Coding*. loc. cit.
[118] Long, CJ., Grieco, PL., and Gozzo, MW. 1989, *Behind Bars: bar coding principles and applications*, PT Publications, Florida. p. 16.
[119] Singer, op. cit., p. 5.
[120] Foster, P. 2004. *San Francisco Airports RFID baggage handling system*. R.F.I.D World Sydney. Aviation Security Manager, San Francisco International Airport.
[121] Interview Participant Two, Appendix A2.

has some believing that RFID will not replace barcodes with human readable information and barcodes still being required, paving the way for the barcodes and RFID to be used in conjunction, a concept echoed by Swartz[122].[123]

4.1.5 Optical Scanning Implications

Barcode technology uses direct 'line-of-sight' when scanning a barcode, requiring each item to be manipulated one at a time.[124] This is because the optical nature of barcodes necessitates labels to be 'seen' by lasers and typically requires close range scanning, often making the technology difficult and impractical in many industrial environments.[125] [126] [127] This characteristic often results in human error, as barcodes often have to be scanned by hand. For example, a warehouse receiving goods of varying dimensions cannot easily automate the scanning of incoming goods, making this a manual process.[128]

Motorola has had to deal with the line-of-site issue in its manufacturing operations. It found that small barcode labels were difficult to scan and apply to transceiver boards with endeavours to use a label applicator machine failing. Subsequently, labels are scanned and applied by hand, making the procedure one of Motorola's few manufacturing processes that is not automated.[129] Line of sight barcode properties have significant consequences when systems are operating in harsh environments, an issue to be covered in later sections.

[122] Swartz, op. cit., p. 21.
[123] Zebra Technologies. 2004. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/WP13467Lreadiness.pdf> Last accessed 29/9/2004. p. 2.
[124] Atock, C. 2003. *Where's My Stuff?*. Manufacturing Engineer, April. p. 25.
[125] Want, R. 2004. *Enabling Ubiquitous Sensing with RFID*. Invisible Computing April, Intel Research. [Online]. <URL: http://www.computer.org/computer/homepage/0404/invisible/r4084.pdf> Last accessed 8/9/2004. p. 84.
[126] Atock, loc. cit.
[127] Sarma, S., Brock, D., Engels, D. 2001. *Radio Frequency Identification and The Electronic Product Code*. MIT Auto-ID Center. IEEE Micro, p. 50.
[128] Donoghue, A. 2004. *RFID: Proceed with caution*. ZDNet. [Online]. <URL: http://www.zdnet.com.au/insight/hardware/0,39023759,39147123,00.htm> Last accessed 27/9/2004.
[129] Heng, Q. 1998. *Bar coding on cellular phones helps Motorola perfect online tracking*. Automatic I.D. News Asia. October/November. p. 24.

4.1.6 Information and Data Properties

Ordinary barcodes store only a small amount of static information, typically around 20 characters.[130] Once the barcode is printed, the static information it contains cannot be changed, updated or reprogrammed as the product moves through the supply chain.[131] Such limited data capacity means that barcodes can generally only identify what type of product a good is, for example a can of Coke, not each individual item.[132] This issue has been partially alleviated by linking barcodes to databases that contain more detailed and dynamic information.

Improvements to barcode symbologies have lead to the development of two-dimensional barcodes, which are capable of storing millions of bytes of information. Swartz comments, "2D [two-dimensional] portable data files fill a conceptual gap, which can redefine the working relationship between people, computers, and documents".[133] 2D barcodes do not depend on links to larger databases, acting as a kind of mini-database themselves, which can include encrypted information.[134]

4.1.7 Environmental Effects

As barcodes require line of sight technology, products must have barcode labels that are clearly visible to make scanning easy. This leads to an inherent hindrance as barcodes are susceptible to damage. To prevent damage, barcodes must be relatively clean, be handled gently in abrasion free environments, nor be exposed to extreme temperatures and harsh surroundings.[135] [136] This can poise a significant problem throughout the supply chain, where goods are often handled roughly and exposed to damaging environments.[137] Barcode readers must also have clean and clear optics to achieve effective scan rates.[138] Harsh environmental conditions such as fog, dirt and

[130] D'Hont, S. (No Date). *The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution*. Texas Instrument TIRIS. Whitepaper. [Online]. <URL: http://www.ti.com/tiris/docs/manuals/whtPapers/manuf_dist.pdf> Last accessed 27/8/2004. p. 3.
[131] Sangani, K. 2004. *RFID Sees All*. IEE Review, Volume 50, Issue 4, April. p. 24.
[132] Lai, loc. cit.
[133] Swartz, loc. cit.
[134] Vernon, loc. cit.
[135] Motorola, Inc. 1997. Electro-Magnetic RFID: Everything You Need to Know About Inductively coupled RFID. Whitepaper. p. 1.
[136] SAP White Paper. *Supply Chain Networks*. op. cit., p. 13.
[137] D'Hont, loc. cit.
[138] Sangani, op. cit., pp. 23 – 24.

rain "are considered to be the downfall of traditional bar codes".[139] Interview participant one outlined a common environment consideration. Many manufacturers and distribution centres run continuously. As barcodes rely on reflective light for reading, sunshine can often hamper barcode scanner read rates and reliability when it is directed at barcode labels.[140]

The oil refinery that interview participant two is employed by uses barcodes to monitor the use of their fire retardant clothing. However, it is common for these barcodes, which are printed onto the clothing, to become damage through general use and washing. When this happens, the refinery has to pay their laundry company to attach a new barcode. This process is an addition cost to the system and requires accurate communication between the refinery and the laundry company, as the new barcode has to be updated on the system. The refinery is looking into the use of RFID tags to solve this problem.[141] 2D barcode technology has partially overcome this intrinsic problem. Should they become damaged the barcode label may still contain useful information and can be read by scanners. This is an important feature when goods are subject to tough operating environments. Testament to this is the fact that the U.S. Marine Corps uses this technology to help manage inventory enroute to conflict zones and once it is on the ground.[142]

4.2 Institutional Standards

For the successful deployment of any emerging technology, established standards are essential. The progression of barcode standards was to move from proprietary to globally accepted open standards. This plays a pivotal role in encouraging uptake of a technology, which, in the case of barcodes, helped the cause of some organisations like Wal-Mart in their quest to encourage others to use the technology throughout the supply chain.

[139] Gerdeman, J. D. 1995. Radio Frequency Identification Application 2000: a guide to understanding and using radio frequency identification. Research Triangle Consultants, North Carolina. p. 27.
[140] Interview Participant One, Appendix A1.
[141] Interview Participant Two, Appendix A2.
[142] Vernon, loc. cit.

4.2.1 Established Quality Standards

The success of barcodes can be largely attributed to the advent of standardisation of symbologies within the industry, with many becoming widely accepted barcode standards.[143] Although the first patent for a barcode was in 1949, it was not until the 1960s and 1970s that industrial and supply chain applications were first used.[144] A particular type of barcode is known as a symbology, which defines "how the information is encoded into the physical attributes of bars and spaces".[145] There are many different kinds of symbologies, each with its own intended industry and characteristics.[146] Standards that have been ratified by major standards bodies help organisations decide which standard to use as standards bodies have already accepted the best barcode symbology standards.[147]

The two most widely used standards are the Universal Product Code (UPC), developed by the Uniform Code Council (UCC) and the European Article Numbering (EAN), developed by the International Article Numbering Association, which were developed for use in the retail sector. The prevalence of these two standards, developed around the thirty years ago, lead to the foundation of the EAN.UCC System of barcode and electronic commerce standards. The "UPC/EAN is the dominate standard in retail" and is used by more than a million companies in 141 nations, primarily for retail applications.[148] [149]

Industrial codes play an important role in streamlining SCM. As industrial codes do not have a single application to solve, unlike the EAN and the UPC for the retail industry, a special group called the Automatic Identification Manufacturers (AIM) manages these standards.[150] Consistency of symbologies is an important consideration for all organisations as this ensures that when they adopt a standard the information is

[143] Long, CJ., Grieco, PL., and Gozzo, MW., op. cit., p. 39.
[144] Long, CJ., Grieco, PL., and Gozzo, MW. 1989, *Behind Bars: bar coding principles and applications*, PT Publications, Florida. pp. 11 – 12.
[145] Palmer, R. C. 1995. *The Bar Code Book- Reading, Printing and Specification of Bar Code Symbols*, Helmers Publishing Inc., New Hampshire. Third Edition. p. 15.
[146] Cohen, op. cit., p. 55.
[147] Long, CJ., Grieco, PL., and Gozzo, MW. loc. cit.
[148] New Jersey Business & Industry Association. 2004. *The Bar Code Hits 30*. [Online]. Available ProQuest Database, Document ID: 688692901. Last Accessed 10/10/2004.
[149] Interview Participant One, Appendix A1.
[150] Collins, DJ. & Whipple, NN. op. cit., p. 25.

universally understood and accepted.[151] This allows the organisations partners to reuse the barcode information throughout the supply chain, adding further value to their products.

4.2.2 Continual Improvement in Standards

Following on from section 4.1.3, which outlined the ongoing improvements in barcode technology, this section will explore how the continual improvement of barcode symbology standards has kept barcodes at the forefront of auto identification in the supply chain. In 1995, there were over 200 catalogued barcode configurations and a great deal more that have been developed by organisations for internal use.[152] The problems involved with having too many standards were alleviated with the advent of autodiscrimination, discussed in section 4.1.3, which allows scanners to become 'multilingual', reading multiple symbologies.[153] Formidable industry groups such as the Automotive Industry Action Group (AIAG), Electronic Industries Alliance (EIA) and the Health Industry Business Communications Council (HIBCC) have developed many industry standards. These standards allow for universal compliance within industries, permitting "identification of product shipments among trading partners in the supply chain" and ensure that dangerous materials are handled in the appropriate manner, increasing workplace safety.[154]

The success of the UPC caused some concern that the code would run out of numbers as the number of companies applying for a UPC customer code rose.[155] One of the inherent limitations of barcodes is their inability to hold large quantities of information. Barcode symbologies generally contain only a small string of numeric or alphanumeric characters.[156] Standards organisations have ensured that barcode standards have kept pace with the needs of the supply chain industry, through the ongoing introduction of new standards. 2D barcodes are a prime example of this as this symbology can store millions of bytes of data with a one inch by two-inch 2D

[151] Zebra Technologies. *Bar Coding 101… What You Need to Know*. op. cit., p. 2.
[152] LaMoreaux, op. cit., p. 65.
[153] Long, CJ., Grieco, PL., and Gozzo, MW., op. cit., pp. 42 – 43.
[154] Zebra Technologies. *Bar Coding 101… What You Need to Know*. op. cit., p. 1.
[155] Long, CJ., Grieco, PL., and Gozzo, MW. op. cit., p. 52.
[156] LaMoreaux, op. cit., p. 68.

barcode being able to store the entire U.S. constitution.[157] Scanners can read the symbology quickly, efficiently and error free thanks to inbuilt error checking, error detection, data reconstruction and redundancy characteristics.[158] [159] Despite this, "there is not a lot of uptake in 2D barcoding in Australia", with participant one expecting to see a surge in the Reduced Space Symbology (RSS) code. RSS involves "taking one UPC barcode, shrinking it down and placing another one on top of it", allowing for the identification of individual items.[160]

The development of 2D barcodes has facilitated General Motors to not only record goods coming in via the receiving dock, but also to provide employees with enough information to direct them to specific put-away locations or even straight to the production line. This improves productivity within the receiving phase and lowers raw material storage space requirements and handling costs. In addition, the more detailed information on each part lets General Motors to track specific parts with more accuracy as they move along the supply chain. This could result in significant goodwill and cost savings as it enables them to take a more specific approach should they have to undertake a general recall of certain parts.[161]

4.3 Organisational Factors

Once the technical and institutional standard side of barcode technology was established, organisations began turning to barcodes in an effort to improve efficiency and control of their SCM systems. This is evident when examining the causative factors for Wal-Mart and other retailers pushing their suppliers to adopt barcode technology in the 1970s. These factors include ongoing attempt to maximise SCM efficiency to lower expenses and gain a competitive edge over rival organisations. Other returns to organisations included the ability to better utilise assets and increase quality control processes. In addition to this, organisations can yield higher returns with superior inventory management capabilities.

[157] Zebra Technologies. *The Basics of Bar Coding*. loc. cit.
[158] Swartz, loc. cit.
[159] LaMoreaux, loc. cit.
[160] Interview Participant One, Appendix A1.
[161] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. op. cit., p. 2.

4.3.1 Asset Tracking

Many organisations turn to barcoding in an effort to help manage their resources. Barcode labels that contain serial numbers are often used as nameplate identification and help organisations with asset tracking operations.[162] The use of barcodes to track specialty tools, manufacturing equipment, computer hardware and office equipment is commonplace in many companies. These barcodes can be linked to a database maintained by the organisation to hold additional information about assets such as cost, maintenance schedules, physical condition and features.[163] Interview participant two's organisation uses a barcode system to monitor their tools. Prior to the systems implementation, the company had no control over tool borrowing. If tool went missing, the company had no way of tracing which tradesperson or contractor had borrowed it. This resulted in the company having to pay for the replacement of many tools and as a number of specialist tools cost in excess of $35 000, this was significant unnecessary expense. Upon the implementation of a barcode system to manage tool usage, the number of tools going missing has dropped and the company has the ability to charge tradespeople and contractors if they borrow a tool and do not return it.[164]

Numerous goods require special reusable packaging containers as they move through the supply chain. Such packaging items include track pallets, milk cartons, trays and other returnable items. Using barcodes to track these objects "can provide a strong return on investment by lowering operating expenses". When these items are not effectively managed, they can often become lost at customer facilities and not be returned promptly. This results in companies purchasing additional "returnable containers to ensure they have an adequate supply, creating excess capacity and locking capital to fixed assets".[165] Barcodes empower companies to permanently identify these items and to scan them to record information and location details as they move in and out of their facilities.[166]

[162] Zebra Technologies. *The Basics of Bar Coding*. op. cit., p. 5.
[163] Zebra Technologies. *Bar Coding 101… What You Need to Know*. op. cit., p. 2.
[164] Interview Participant Two, Appendix A2.
[165] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. op. cit., p. 7.
[166] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. loc. cit.

4.3.2 Inventory Tracking

Barcodes provide organisations with an "effective tool for basic inventory tracking".[167] The advent of barcoding inventory has yielded numerous advantages to organisations allowing them to accurately manage inventory levels.[168] Zebra cites an example of a baking company reducing its inventory and distribution costs by US$3 million in the first year after implementing an inventory tracking system. Monitoring and capturing more information on their products allowed the company to "gain an accurate, timely view of inventory and to increase the average number of pallets per shipment from 47 to 61", some 30% improvement.[169] The savings offered through more effective inventory management in the supply chain with barcodes will be explored in the subsequent chapter.

4.3.3 Inventory Management and Traceability

Enhanced inventory management is made possible through item level inventory tracking with barcodes, as discussed in the preceding chapter. Participant 1 believes that in terms of barcode technology in SCM, "the big thing is inventory control".[170] At a high level, barcodes allow organisations to have inventory details at all times, including information on location, quantity and other details. This permits companies to minimise product search times, improve inventory control and ensure they have enough inventories on hand to meet demand, while enhancing productivity and efficiencies of scale.[171]

Organisations are also better equipped to monitor order fulfilment processes and quickly meet order demands even as they reduce labour costs by eliminating manual steps.[172] With the prevalence of modern just in time (JIT) inventory management and built-to-order SCM practices, the need for immediate and accurate reporting is paramount. Barcodes offer the means for companies to meet these requirements by

[167] Intermec Technologies, 2002. *RFID Technology In Retail*. White Paper. p. 2.
[168] Thompson, loc. cit.
[169] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. op. cit., pp. 1 - 2.
[170] Interview Participant One, Appendix A1.
[171] Zebra Technologies. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. op. cit., p. 2.
[172] ibid.

delivering the efficiency required by such methods as JIT.[173] [174] Barcodes also aid organisations in reducing operational inventory levels, increasing working capital.[175]

Hau Lee, a professor at Stanford's business school thinks that when it comes to barcodes and inventory management, "Wal-Mart is certainly the champion". Enhanced inventory management practices throughout their supply chain has allowed them to keep both costs and prices down by using barcode systems, which benefits both the company and the consumer. Wal-Mart stores use wireless scanners, allowing staff to make price changes, place orders and view sales histories of products. This in turn means that stores can be flexible, tweaking prices on a popular item for example, which is a crucial need for a worldwide supply chain.[176] This helps to ensure that companies do not run out of stock for a particular item, as systems can alert staff when specific product quantities are running low.[177] Australian retailer, David Jones, uses a similar system that allows staff to use wireless barcode scanners. David Jones has found the system particularly useful when employees are doing inventory stocktakes. The system has been very successful and the retailer is investigating the possibility of expanding it to include wireless point-of-sale terminals.[178]

Zebra Technologies note that for companies "with millions of parts to identify, locate and move in and out of inventory, bar coding is essential". Warehouse management systems (WMS) linked with barcode systems can help route workers directly to optimised put-away locations depending on a good's shelf-life, size and predicted consumption schedule. A baker and snack food producer with national distribution requirements was able to achieve improved tracking over work-in-progress and finished goods, reducing inventory distribution costs by 30%.[179]

[173] Zebra Technologies. *Bar Coding 101… What You Need to Know*. op. cit., p. 1.
[174] Interview Participant One, Appendix A1.
[175] Cohen, op. cit., p. 153.
[176] Varchaver, loc. cit.
[177] Thompson, loc. cit.
[178] Crowe, D. 2004. *DJs to upgrade for faster service*. The Australian Financial Review. p. 53.
[179] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. op. cit., p. 3.

4.3.4 Quality Control and Recall Management

Sound and thorough inventory management practices also lead to more advanced lot management and quality control capabilities. Long et al note, as companies begin to "automate and to use Just-In-Time (JIT), Total Quality Control (TQC) and Computer Integrated Manufacturing (CIM) in the management of their operations, then bar coding will become the veins and arteries which carry that information".[180] When used for quality and lot control purposes, barcodes contain such internal information as completion dates, serial numbers, materials used and miscellaneous quality control information. Organisations can scan these barcodes as items leave their shipping department and record exact details of products to record information such as destination in real-time. Motorola uses "tiny barcodes as part of its quality assurance in its manufacturing process to correctly identify assemblies".[181]

The cost of a product recall is determined by the degree of traceability that organisations have on their products. "The amount of information included on unit-of-use packaging can make the difference between a general, mass recall with notices going out in newspapers and TV news, and a highly targeted, limited recall where customers may receive notification by a phone call from their supplier". First class quality controls have contributed significantly to decreasing the likelihood of a product recall.[182]

Enabling barcodes to track items at lot level throughout the supply chain means that specific quantities and shipment lots can be recalled should there be a problem. Returned goods can be easily checked with a barcode scan, limiting the burden on staff in the advent of a recall. "This degree of traceability limits the logistics handling costs and administrative burden, so recalls can be resolved more quickly" and creates an audit trail that would "limit liability exposure and prevent lawsuits from unaffected individuals".[183] General Motors have saved millions in costs and damage to its

[180] Long, CJ., Grieco, PL., and Gozzo, MW., op. cit., p. 136.
[181] Heng, op. cit., p. 23.
[182] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. op. cit., p. 7.
[183] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. loc. cit.

reputation through higher level lot tracking with its two dimensional shipping labels.[184]

4.3.5 Limited Visibility

While manual data entry using keyboards is "slow, dependent on human operators, inaccurate and expensive", some believe that barcodes constrain modern supply chains.[185] This is because manual intervention and line of sight scanning are needed to cope with the technical limitations of barcodes. Barcode scanning is a process that is labour intensive requiring the scanning of multiple pallets and products to be performed numerous times as a product moves through the supply chain. IBM notes that all of this drives up cost and inefficiency into the already complex supply chain where retailers often "lack visibility into on-hand inventory, and have difficulty managing shrinkage and keeping their shelves stocked appropriately".[186]

4.4 Economical Considerations

One of the later realisations in the barcode diffusion cycle was the economical saving. Once the deployment of barcodes in SCM approached critical mass, large savings could be achieved in numerous ways including reduced error levels, increased visibility and labour reduction. This will be the final barcode adoption stage explored by this thesis.

4.4.1 Timely Information and Reduced Errors

There is no doubt that barcode technology is faster than manual keyboard data entry, which depends on human operators, and is slow, inaccurate and expensive.[187] Information can be read from a barcode in less than a second, giving an organisation immediate information on a products lot number, invoice data order number and other

[184] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. op. cit., p. 2.
[185] Long, CJ., Grieco, PL., and Gozzo, MW. op. cit., p. 16.
[186] IBM Business Consulting Services. 2004. *Streamlining the supply chain using radio frequency identification*. IBM Whitepaper. [Online]. <URL: http://www-1.ibm.com/services/us/bcs/pdf/g510-3839-streamlining-supply-chain-using-radio-frequency-identification.pdf> Last accessed 27/9/2004. p. 2.
[187] Long, CJ., Grieco, PL., and Gozzo, MW. loc. cit.

information attributed to the barcode. Section 4.1.4 explained in some detail the accuracy of barcodes compared to manual data entry. Zebra Technologies note that gathering information manually "is time consuming, because the information first must be recorded at the point of activity, then later transcribed and entered into the computer system", every additional stage increasing the already high chance of error.[188]

The real-time information provided by barcodes provide allows organisations to base their decisions on current, accurate and concrete information.[189] Such information can provide companies with a competitive advantage through their supply chain management practices. For example, if a company receives timely and accurate information they may be able to operate with a greater warehouse capacity or lower inventory on hand through employing JIT inventory practices. JIT allows companies to predict precisely when they will run out of stock and place orders with suppliers to replenish stock levels. Although this can be risky, when properly implemented it can yield enormous savings.[190] This means the company can keep stock levels at a minimum. JIT helps to reduce "inventory levels and overall inventory carrying costs", maximising working capital for a business to invest in other areas.[191]

4.4.2 Efficiency Benefits

The key motivations for organisations to utilise barcoding are generally the same across organisations; to improve data management, accessibility and reduce costs.[192] It is estimated that in the domestic retail industry of the U.S, barcodes save over US$17 billion annually.[193] According to Zebra Technologies, barcoding "enhances productivity and efficiencies of scale, and reduces costs".[194] There is a plethora of literature, mainly in whitepapers, with case studies on organisations saving significant amounts of money and improving efficiency through the utilisation of barcode

[188] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. op. cit., p. 2.
[189] Zebra Technologies. *The Basics of Bar Coding*. op. cit., p. 2.
[190] Cohen, op. cit., p. 156.
[191] Zebra Technologies. 2003. *Bar Codes and Manufacturing*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/BarCodesManufacturing.pdf> Last accessed 28/9/2004. p. 4.
[192] Zebra Technologies. *Bar Coding 101… What You Need to Know*. loc. cit.
[193] New Jersey Business & Industry Association. loc. cit.
[194] Zebra Technologies. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. loc. cit.

technology.[195] [196] [197] Improved labour efficiencies are a significant contributor to overall cost savings delivered through barcodes and as such, an entire section will explore this is issue in a later section.

Section 4.1.1 noted that barcode labels can yield organisations considerable media savings as they are much smaller than traditional paper forms. Automation of processes can dramatically increase speed and efficiency throughout the supply chain without risking accuracy.[198] Testament to this is the fact that around 80% – 90% of Fortune 500 companies have automated their warehouses with barcode systems.[199] Automation of formerly manual tasks enables personnel to be more productive in other areas of an organisation's operations.[200]

An example of an efficiency gain through barcode technology can be demonstrated by examining United Postal Service (UPS). The company predicts that they will save US$600 million a year when their barcode system is fully operational in 2007. These savings are largely delivered through enhanced automation and employee utilisation with barcode technology. General Motors have used barcodes in the assembly line of some of their plants, successfully reducing errors, such as installing the wrong parts, from 15% to 0%. Furthermore, section 4.3.4 noted that the company has also saved millions in costs and damage to their brand through the barcode tracking of parts in its supply chain. Other examples include Procter & Gamble, who realised double-digit productivity improvements through automation and Kimberly-Clark, who reduced shipping errors by more than 50% with barcode technology.[201] Similarly, each error in the shipping process at DePuy Orthopaedics costs between US$35 and $65 to resolve. After implementing a barcode system for shipping operations the company has saved several hundred thousand dollars.[202]

[195] Varchaver, loc. cit.
[196] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. op. cit., p. 1.
[197] Vernon, loc. cit.
[198] Zebra Technologies. 2003. *Bar Coding 101… What You Need to Know*. op. cit., pp. 1 - 2.
[199] Varchaver, loc. cit.
[200] Zebra Technologies. *The Basics of Bar Coding*. op. cit., p. 4.
[201] Varchaver, loc. cit.
[202] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. loc. cit.

4.4.3 Proven Technology with Existing Infrastructure

The preceding section provided some specific examples of successful barcode implementations, many in multinational organisations requiring significant infrastructure. Since the inception of barcodes more than 30 years ago, the technology has been turned to by many industries and applied throughout the supply chain. In fact, barcodes have evolved to meet demands throughout the enterprise including warehousing, package delivery, accounting and customer service functions.[203] Singer comments that "bar coding is a proven, well-established technology", as evidenced by the fact that worldwide, barcodes are scanned over 10 billion times a day.[204]

Many organisations, in particular most mid to large sized distribution intensive operations, have adopted barcoding technology and invested considerable amounts of capital in infrastructure and related systems. Such organisations would need to thoroughly assess the benefits of any other auto-ID technology before being able to justify investment in an alternative technology.[205] Furthermore, the wide array of barcode standards[206] contributes to the established and accepted state of barcodes.

4.4.4 Labour Considerations

It takes less than a second to scan a barcode, making barcode scanning faster than manual collection, improving labour productivity and reducing labour costs.[207] [208] However, with barcode technology commonplace in the supply chain and the popularity of manual data fading, there is more focus on the labour requirements required by the physical nature of barcode scanning. This is due to the technical line-of-sight attribute of barcodes and the increasing popularity of radio frequency identification (RFID) technology that is not bound by the limitations of optical line-of-site.[209] Jimmy Burk, a FedEx information technology vice president recalls when the company had "people specially trained to memorize about 300 routes in our hubs,

[203] Zebra Technologies. *Bar Coding 101… What You Need to Know*. op. cit., p. 1.
[204] Singer, op. cit., p. 2.
[205] Vernon, loc. cit.
[206] See section 4.2.1.
[207] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. loc. cit.
[208] Zebra Technologies. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. loc. cit.
[209] Sanford, V. 2003. Pervasive Computing Goes the Last Hundred Feet with RFID Systems. IEEE CS and IEEE ComSoc, April-June. p. 9.

to know the zip codes and the cities so that they could put them on these special conveyors, because there was no automation".[210] Barcodes have empowered such organisations to automate sorting processes, as is evident with the examination of UPS in the previous section.

To scan an object it needs manipulation by hand, one at a time, a process that may often require additional labour.[211] Furthermore, the physical nature of barcoding with manual scanning introduces the likelihood of mistakes made by operators scanning barcodes.[212] IBM has stated that supply chains are "constrained by barcode scanning, which requires line-of-sight visibility and manual intervention that can limit timely access to data". This physically demanding process of scanning many barcodes means that manufacturers, retailers and logistic transport organisations often spend innumerable days "physically checking pallets and cases of products as they move through the supply chain".[213]

4.4.5 Human Error

Section 4.1.4 noted that a manual data entry operator typically makes one error for every 300 characters entered, whereas a barcode scanner makes one error every one million characters or better. Barcode scanning eliminates manual data entry to provide near perfect identification of objects.[214] This makes the technology far superior for entering data into a system than manual word processing or manual record keeping with paper forms and pen, as noted by interview participant 1, "it [barcodes] destroys human error".[215] [216] As previously discussed, DePuy Orthopaedics eliminated its manual data entry with a barcode system, significantly reducing shipping errors, yielding savings of several hundred thousand dollars.[217] Similarly, Online Express

[210] Varchaver, loc. cit.
[211] Atock, loc. cit.
[212] Singer, loc. cit.
[213] IBM Business Consulting Services. loc. cit.
[214] Singer, op. cit., p. 5.
[215] Zebra Technologies. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. op. cit., p. 1.
[216] Interview Participant One, Appendix A1.
[217] Zebra Technologies. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. loc. cit.

Parcels has taken advantage of barcodes to reduce the risk of human error, through more accurate barcode information management practices.[218]

In the medical industry, human error in managing the supply chain of medicine distribution can have devastating consequences in the advent of human error. The industry has turned to barcode technology to address this issue. According to the Institute of Medicine and other experts, "thousands of deaths and millions of hospitalizations result from medication errors". The annual benefit from preventing these errors is the equivalent to saving US$3.9 billion.[219] By barcoding a patient's information and medicines, facilities could reduce errors by around 65% to 86%, a significant benefit to all stakeholders.[220]

There is however, one common weakness with manual scanning in that it requires the operator to actually perform the scan. Singer notes that even with barcode systems in place, inventory still gets lost and incorrect shipments are still made because "a warehouse associate performed an inventory move without performing the corresponding scan transaction".[221] A delivery company in the UK, Online Express Parcels, attributes human error for the reason parcels are often misrouted or left behind. The company has employed a barcode system to help stem this problem; however, it too is subject to human error.[222] Further weight is given to this notion with Zebra Technologies acknowledging that barcode "shipment verification requires operators to scan each label, raising the possibility that items could be missed and unaccounted for".[223]

[218] Vernon, loc. cit.
[219] United States Department of Health and Human Services. 2003. *Secretary Thompson Announces Steps to Reduce Medication Errors: FDA Proposals for Medication Bar Coding and Safety Reporting Will Improve Patient Safety*. [Online]. <URL: http://www.os.hhs.gov/news/press/2003pres/20030313.html> Last accessed 17/10/2004.
[220] Heinen, MG, Coyle, GA, Hamilton, AV. 2003. *Barcoding makes its mark on daily practice*. Nursing Management, October. p. 18. [Online]. Available ProQuest, Document ID: 442886571. Last accessed 17/10/2004.
[221] Singer, loc. cit.
[222] Vernon, loc. cit.
[223] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 3.

Chapter 5 – The Emergence of RFID

The development of RFID technology for use in supply chain management (SCM) is relatively immature. There are still no open industry standards endorsed by major standards organisations, which has impeded radio frequency identification (RFID) from progressing throughout the supply chain. However, RFID's deployment in SCM can be viewed as inevitable once open industry standards are developed. Due to such limitations, RFID remains at an early stage of its lifecycle and as a result, there is a lack of depth concerning the normal adoption cycle, which was used to structure the preceding chapter on mature barcode technology.

This chapter is based on the technical characteristics of RFID, as the development of the technology at an early stage, remaining between the technological and standard phases of its development. Particular focus will be given to emerging issues such as technologic characteristics and standards, which relate to the development of RFID. The layout will cover the most dominant technical aspects such as non-line-of-sight reading first, to the less dominant characteristics, such as deployment issues. Numerous current cases will be used to illustrate issues, providing specific, factual information to support the research.

5.1 The Effects of Non-Line-of-Sight Technology

5.1.1 Automatic Non-Line-of-Sight Scanning

One of RFID's most attractive offerings is its fundamental attribute of not requiring line-of-sight when reading RFID tags. This means items do not require particular orientation for scanning, unlike barcodes. Singer noted, "RFID's promise of a scan-free supply chain is too attractive to ignore".[224] At a high level, this inbuilt technological characteristic acts as an enabler leading to a plethora of advantages at numerous levels throughout the supply chain.

[224] Singer, op. cit., p. 2.

RFID scanners can communicate to tags in milliseconds and have the ability to scan multiple items simultaneously.[225] [226] This ability significantly aids the automation of many SCM tasks that have typically been labour intensive roles such as checking and scanning incoming inventory.[227] [228] This provides the means for an organisation to accurately add an entire pallet of items instantaneously to its inventory system, removing the need to unpack any items from pallet loads.[229] Subsequently, organisations have a more current and accurate picture of stock levels. This in turn means lower inventory costs and less out of stock occurrences, both of which will be discussed in more depth in later sections.

5.1.2 Labour Reduction

RFID promises to help automate the supply chain to unprecedented levels, leading to labour reduction throughout the supply chain.[230] [231] Furthermore, a reduced level of labour contact contributes to efficiency in the supply chain. Supply chains typically require staff for the laborious task of orientating objects to allow their barcodes to be scanned, however RFID tagged items can be scanned regardless of their orientation. [232] [233]

The major cost component for typical distribution centres is labour, accounting for around 50-80% of their total distribution costs. Diagram 5.1 shows the labour breakdown of a typical distribution centre.

[225] Motorola, Inc. loc. cit.
[226] Sanford, loc. cit.
[227] Intermec Technologies, op. cit., p. 1.
[228] Sarma, S., Brock, D., Engels, D. loc. cit.
[229] Shim, R. 2003. *Wal-Mart to throw its weight behind RFID.* CNET News. [Online]. <URL: http://news.com.com/2102-1022_3-1013767.html> Last accessed 26/8/2004.
[230] Intermec Technologies, op. cit., p. 2.
[231] Finkenzeller, op. cit., pp. 4-30 – 4-31.
[232] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., pp. 2 – 4.
[233] Singer, op. cit., pp. 4 – 5.

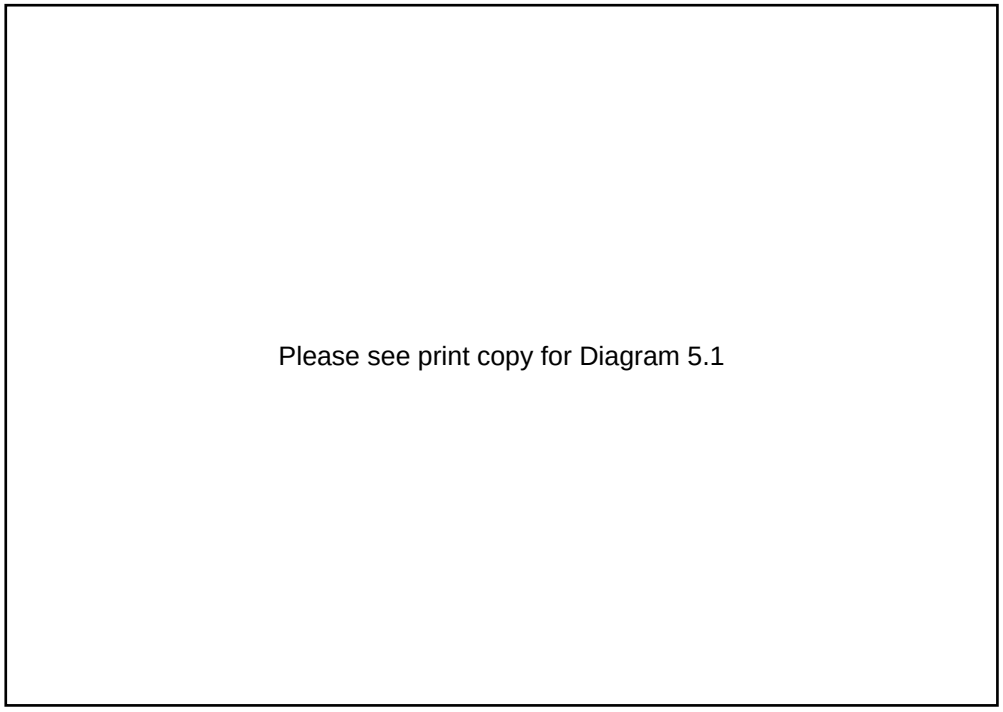


Diagram 5.1: A Typical Distribution Centre's Labour Breakdown

(Source: Keith, A. et.al.)[234]

Keith, et al., predict that receiving check-in time could be reduced by 60 – 93% with RFID technology. It is also estimated that RFID could yield labour savings of up to 36% in order picking and a 90% reduction in verification costs for shipping processes. These figures demonstrate the significance of labour in supply chains and that even small reductions can deliver considerable financial savings.[235]

Motorola notes that the increased level of automation resulting in reduced human intervention "improves the value of the information in a system by making it available sooner". This can have profound implications when items have been mis-routed, as the information is picked up earlier, allowing corrective action to be taken in a reduced timeframe.[236] Automation also reduces the likelihood of errors being made at most stages and for most tasks in the supply chain.[237] Amcor Fibre Packaging has been able to reduce the number of employees on each shift through its internal RFID

[234] Keith, op. cit., p. 14.
[235] Keith, op. cit., pp. 13 – 14.
[236] Motorola, Inc. loc. cit.
[237] IBM Business Consulting Services. op. cit., p. 8.

supply chain system.[238] Another example of labour reduction can be gained by examining Collex's recent RFID implementation. Prior to the new RFID system, drivers had to get out of their trucks at landfills, manually enter their waste details and wait for a ticket. Drivers were also required to wait for a ticket when leaving the landfill; in all a time consuming process. When truck drivers now enter a landfill, they merely have to stop on the weighbridge, hold their RFID tag next to the reader and wait a second for their printed ticket.[239]

Retailers in particular, stand poised to benefit from RFID, as they can remove the large labour component required to manage stock in their stores and move those costs to manufacturers.[240] Furthermore, RFID ultimately promises the inception of instantaneous operator free checkouts.[241] [242] The reduction of human intervention leads to more responsive and transparent supply chains for organisations at all levels.

5.1.3 Enhanced Visibility

The pervasive 'always-on' nature of RFID technology equates to greater visibility to all stakeholders in the supply chain. It is estimated that the U.S. retail industry is losing about "US$70 billion annually" from its SCM practices. About 42% of this comes from product not being on the retail shelf for consumers, with the remainder derived through losses within the supply chain.[243] The visibility offered by RFID could help to reduce this loss, by reducing waste, lowering inventory levels and improving safety and security.[244]

[238] Wind, G. 2004. *Creating business intelligence from what were black holes of information and data*. R.F.I.D. World Sydney. Amcor Fibre Packaging.
[239] Mills, K. 2004. *Tags weigh in for landfill trucks*. The Australian, IT Business. p. 3.
[240] Brand, J. 2004. *RFID: Why business wants it*. Interview with Richard Aedy. The Buzz. ABC. Transcript available online <URL: http://www.abc.net.au/rn/science/buzz/stories/s1054968.htm> Last accessed 28/2/2004.
[241] RFID Survival. 2004. *RFID and Walmart*. [Online]. <URL: http://www.rfidsurvival.com/RFIDandWalmart.html> Last accessed 22/7/2004.
[242] Atock, op. cit., pp. 25 - 26.
[243] Teresko, J. 2003. *Winning with wireless*. Industry Week, Vol.252, Iss. 6; pg. 60. [Online]. Available ProQuest, Document ID: 345556831. Last accessed 12/10/2004.
[244] SSA Global Technologies, Inc. 2004. *Get ready for real-time supply chain visibility*. [Online]. <URL: http://www.ssaglobal.com/scm/rfid.pdf> Last accessed 28/9/2004.

Improving visibility in the supply chain can help "lower distribution and handling costs and reduce inventory levels".[245] RFID allows products to be followed in real-time across the supply chain providing accurate and detailed information on all items, allowing organisations to use this information to increase efficiency. As objects move along the supply chain, their information can continuously be accessed and updated.[246] Inventory visibility can be used to achieve gains in areas such as faster response to customer demands and market trends, improving the ability to have the right product in the right place at the right time.[247] Wal-Mart's RFID strategy manager, Simon Langford, noted that Wal-Mart has visibility today, but it is quite fragmented. He believes that RFID is all about total supply chain visibility.[248]

Real-time information can be obtained through 'smart shelves', which have inbuilt RFID tag receivers. This would help retailers track the exact number of products they hold and other useful information such as expiry dates.[249] Such technology would help ensure that shelves always have stock, reducing the US$30 billion dollar loss from product not being on shelves in the U.S. as noted at the beginning of this section.[250] Readers can also be built into the floors and doors of warehouses and distribution centres for similar applications like monitoring storage areas.[251]

5.1.4 Asset Tracking and Returnable Items

Asset tracking is currently one of the most common applications of RFID technology. A recent Aberdeen Group survey of 200 companies found that more than half of the companies with RFID systems were using the technology in asset tracking.[252] RFID is ideal for identifying items that require routine calibration, inspections, or that need to be checked in or out. Another advantage of using RFID technology to track assets

[245] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 3.
[246] Atock, op. cit., p. 26.
[247] SAP AG. 2004. *Putting RFID on the Fast Track*. [Online]. <URL: http://www.sap.com/solutions/business-suite/scm/rfid/brochures/index.aspx> Last accessed 28/9/2004. p. 1.
[248] Donoghue, loc. cit.
[249] The Wall Street Journal. 2004. *Retailers in race for wireless chip*. The Australian Financial Review. p 68.
[250] Atock, op. cit., p. 25.
[251] IBM Business Consulting Services. op. cit., p. 2.
[252] Albright, B. 2004. *RFID Tag Placement*. [Online]. <URL: http://www.frontlinetoday.com/frontline/article/articleDetail.jsp?id=98552> Last accessed 7/9/2004. p. 2.

such as tools is that the tags are virtually undetectable.[253] RFID can also track an asset's movement, use, and placement, helping to improve asset utilisation.[254]

Shipping companies find it difficult to track containers as they are continually transported around the world. RFID can help shipping and logistics organisations accurately track such valuable assets. In addition, RFID systems can log a container's history; if a container has been used for the delivery of dangerous items such as chemicals, RFID tracking can be used to ensure that government requirements and regulations are complied with.[255] [256]

Many products require special reusable containers or packaging for transportation purposes as they move along the supply chain. Objects such as beer kegs can be expensive to produce and difficult to track. A company called TrenStar has successfully developed a system using RFID technology to manage beer kegs as they move throughout the supply chain.[257] Another example of tracking reusable containers can be found by examining Colorpoint and MidAmerican Growers, who use an RFID based system to track metal carts worth US$400. The carts, which are sent to retailers laden with plants and flowers, were being lost at a rate of 5%. The new system means that these companies have comprehensive information on where the carts have been sent and can query retailers who have not returned them. [258]

5.2 The Need for Accuracy

5.2.1 Item Level Tracking

Intermec Technologies claim that the "ultimate goal in retail is to create RFID systems that provide the benefits of the technology at a cost that supports item-level tracking", allowing every individual product a unique identification number. They forecast that once item-level tracking is achieved, "physical inventories and product re-ordering will be done in a fraction of the time it now takes and retailers will be able

[253] Motorola, Inc. op. cit., p. 11.
[254] Keith, op. cit., p. 18.
[255] Motorola, Inc. op. cit., p. 12.
[256] Finkenzeller, op. cit., pp. 244 – 245.
[257] Albright, loc. cit.
[258] Albright, loc. cit.

to take inventory much more frequently".[259] Item-level tracking opens the door to a whole range of potential benefits, for example theft detection or customised manufacturing.[260]

The concept of 'smart-shelves', as discussed, in section 5.1.3, is where shelves have inbuilt RFID scanners allowing them to automatically monitor stock on the shelves. For 'smart-shelves' to realise their maximum potential, item-level tracking is a necessity, providing the means for individual products, such as each can of coke.[261] It also allows management systems to identify and store individual product properties such as expiry dates.[262] [263] Inventory systems also have the capacity to monitor inventory from a more accurate position.

According to Wal-Mart, fully automated item-level tracking for all products, though applications like automatic checkouts, is not likely to be introduced for around 10 – 15 years.[264] One of the main reasons for this is the current high cost of the technology.[265] Gillette, who is currently trialling item-level tracking, "foresee item-level tagging in production for at least 10 years", citing that the costs of RFID tags would need to drop to around one cent or less for it to happen. [266] In the near future, most organisations have decided to focus on pallet and case level tracking.[267] [268]

5.2.2 Traceable Warranties and Product Recalls

Product recalls can be attributed as a costly source of loss in the supply chain. This is often because it is extremely difficult for organisations to "pinpoint only the specific faulty instances of a product" which "often leads to the destruction of perfectly good products".[269] As discussed in section 4.3.4, the level of information included on a

[259] Intermec Technologies, op. cit., p. 3.
[260] Atock, op. cit., p. 26.
[261] Atock, op. cit., p. 25.
[262] The Wall Street Journal. loc. cit.
[263] Atock, loc. cit.
[264] Donoghue, loc. cit.
[265] ibid.
[266] See section 5.5.3 for more information.
[267] Sliwa, C. 2003. *RFID Tags Gat Cheaper*. Computerworld. [Online]. <URL: http://www.computerworld.com/printthis/2003/0,4814,84004,00.html> Last accessed 26/9/2004.
[268] Interview Participant One, Appendix A1.
[269] VeriSign. op. cit., p. 4.

units packaging can be the difference between making a mass recall, requiring extensive advertising and large quantities of possibly non-faulty product being recalled, or a highly specific and personalised tracking of customers who have purchased the faulty products.[270] RFID and the Electronic Product Code (EPC) can uniquely identify every individual item in the supply chain, allowing manufacturers to obtain instant access to information that allows them to issue targeted recalls of only affected products. Subsequently, suppliers can minimise their exposure, which helps organisations maintain a strong and trusted band name with such capabilities only adding to their goodwill. Tags items that require repair and are covered by a warrantee can be authenticated, ensuring that the warrantee period of the product has not expired. The item can also be monitored as the product moves back up the supply chain to the manufacturer or authorised repairer, allowing customers to receive detailed information on where their item is.

5.2.3 Reliability

The reliability of RFID tags is an issue that could make or break their widespread success. A multitude of pilot tests that have been carried out under a variety of operating environments. One objective of pilot tests is to assess the reliability of RFID tags. Airports are testing the technology to help track baggage and supplies, while manufacturers are using the technology to manage incoming and outgoing inventory. While some RFID tags are currently not achieving satisfactory read rates, there are numerous applications that are achieving high reliability with accurate read rates. The consensus is that for applications that are not achieving high quality read rates, it is merely a matter of time and experience with the new technology before solutions to the problems are found.[271]

The RFID community has devoted a large volume of research to airport baggage tracking trials that use RFID. After performing numerous trials and tweaking their RFID system, San Francisco International Airport has been able to reach read rates consistently above 99.5% in a production environment.[272] Similarly, an RFID bag-

[270] Zebra Technologies. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. op. cit., p. 7.
[271] Sliwa, loc. cit.
[272] Foster, loc. cit.

tracking system in Jacksonville, USA, "provided read rates well above 99%", at all stages of the tracking chain.[273] General Motors have added parity bit checking, so that once a tag has been written to, they are "100% assured it's error-free".[274] Another example is Amcor Fibre Packaging who has achieved accuracy of better than 98%. The occasional error with Amcor's inventory management system can usually be attributed to human error.[275]

Despite many promising applications, John Brand, a technology consultant from Meta Group, notes that tags are still not 100% reliable with anything from 3 – 5% error rates. This is considered a high error rate compared to other forms of stock reconciliation using barcodes.[276] Some users have experienced "read rates of less than 80%" with RFID tags. However, a common reason for this is that many organisations have not sufficiently considered around interference problems. The difficultly of transmitting clean radio signals has been a factor in limiting the reliability of RFID, a problem that barcodes do not have to contend with. Interference is a significant deployment consideration, which will be discussed in depth in section 5.6.[277]

5.3 Tag and Data Characteristics

5.3.1 Quality Control and Regulation

RFID empowers organisations to monitor the quality of products not only internally within their manufacturing process, but also as their goods move along the supply chain.[278] The technology permits the collection of real-time information in the manufacturing process for quality control purposes, lowering the chance of customers receiving poor quality products as well as reducing the time spent monitoring and reworking orders.[279] Tags can monitor things like temperatures, bacteria levels and provide tamper evidence, regardless of the product position in the supply chain.[280]

[273] Brewin, loc. cit.
[274] Finkenzeller, op. cit., p. 4-34.
[275] Wind, loc. cit.
[276] Brand, loc. cit.
[277] Sliwa, loc. cit.
[278] Sarma, S., Brock, D., Engels, D. loc. cit.
[279] Cohen, op. cit., p. 149.
[280] IBM Global Services. 2004. *Beyond the bar code: Transforming business with Radio Frequency Identification*. IBM Corporation. [Online]. <URL: http://www-

This is an important capability in modern supply chains where many products are shipped around the world, exposing them to countless environmental stresses, all of which could hamper the quality of the finished good.

Currently some package delivery companies monitor goods with non-electronic dye-based tags which change colour should they receive an excessive impact or vibration. This technology is often used to monitor fragile goods, which can only withstand limited stresses. The method slows down the supply chain as it requires each product to be manually inspected. Smart semi-active or active RFID tags can monitor such environmental forces, increasing the speed and lowering the cost of this phase of SCM as RFID readers can automatically detect such events without necessitating the inspection of each product.[281] For example, the U.S. army is piloting the use of RFID tags with "battery-powered sensors that can monitor temperatures in the areas where goods are shipped and stored". The tags are being placed with food sent to troops in the field and are designed to ensure that food is used before the shelf life is exceeded. High temperature conditions can significantly reduce the shelf life of U.S. army rations from the normal average of 3 years to just 1 month. The RFID technology will ensure troops receive quality uncontaminated food.[282]

RFID tags used within the EPC Network can also reduce the incidence and negate the impact of counterfeiting. Smart RFID tags can also provide failsafe tamper protection, electronically recording when a product's packaging has been breeched. There is also no need for the physical inspection of each product as an entire pallet can be scanned and checked for tamper evidence in seconds with RFID readers.[283] These qualities of RFID are of particular importance in the pharmaceutical industry where drug counterfeiting and tamper protection are hot topics.[284]

1.ibm.com/industries/wireless/doc/content/bin/Beyond_the_Barcode.pdf> Last accessed 1/10/2004. p. 2.

[281] Want, op. cit., p. 85.

[282] Brewin, B. 2003. *Army to test passive RFID tags on food shipments*. Computerworld. [Online]. <URL: http://www.computerworld.com/softwaretopics/erp/story/0,10801,87623,00.html> Last accessed 24/10/2004.

[283] Savi Technology. op. cit., p. 7.

[284] VeriSign. op. cit., p. 3.

5.3.2 Yard, Warehouse and Factory Management

In today's business operating environment, it is important that business achieve the maximum productivity available from their assets. Organisations often have large levels of capital tied up in yards and factories and as such, they need to be managed efficiently. Operating in a more efficient manner not only helps organisations maximise their return from these assets, but contributes to their overall competitive advantage throughout the supply chain, aiding them to keep pace with concepts such as just in time (JIT) inventory management.

It is difficult to for organisations managing large yards to know what goods are on which truck without first unloading the truck, which also makes it complicated to direct the truck to the right drop off or parking yard location. RFID technology stands poised to solve this logistical hindrance. RFID tags can be placed on truck trailers and RFID readers placed at entry and exit points of yards allowing management systems to log the incoming and outgoing data in real-time. This information enables systems to log the incoming inventory and direct the truck driver to the most efficient drop-off location. Items are unloaded faster with the yard being managed in the most resourceful manner, maximising an organisation's utilisation of the asset and order fulfilment capabilities.[285] [286]

The system discussed in the preceding paragraph can also be applied to forklift operators working in warehouses, directing them exactly where they need to go in the most efficient manner. Motorola predicts that the use of RFID technology in warehouse management system's (WMS) will be a potential area for large growth.[287] Amcor Fibre Packaging successfully uses RFID to manage its warehouse. Before the system was implemented, their warehouse would often reach 2500 pallets, 500 more than what the warehouse was designed for requiring production to be stopped. In addition to this, there "would be between 15 and 25 trucks waiting to be loaded". The new RFID capable WMS has reduced the typical number of pallets in the warehouse

[285] Keith, loc. cit.
[286] Motorola, Inc. op. cit., p. 17.
[287] ibid.

to 800 with no more than 2 to 5 trucks waiting. Since the systems inception, production has not been stopped.[288]

5.3.3 Improved Inventory Management

Manufacturers persistently struggle to get the right products to the right retailers at the right time.[289] RFID can help solve this problem while reducing inventory levels and lowering distribution and handling costs by providing accurate and real-time information on inventory quantities and movement.[290] The technology promises to transform the way organisations currently "forecast demand, manage inventory and distribution, and market to consumers within the store".[291] The 'always on' properties of RFID means that inventory management systems can know where products are in the supply chain at any time.[292]

Visibility[293] and item level tracking[294] are pivotal to effective inventory management. Both of these sections discussed the concept of smart-shelves, which would allow all exact inventory stocktakes to be carried out instantaneously throughout the supply chain, thanks to RFID's non-line-of-sight property. It can relay "data about location, design and history". This can help companies avoid out-of-stock situations while reducing costs.[295] [296] The prevention of out-of-stock occurrences is important, with research revealing that out-of-stocks can be as high as 17% for some fast-moving items. The average out-of-stock occurrences for items the grocery sector is 7% of the time.[297]

RFID can enhance inventory management in a number of ways, for example, RFID systems can improve the ability to forecast product demands by 10 - 20% when

[288] Wind, loc. cit.
[289] IBM Business Consulting Services. op. cit., p. 8.
[290] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. loc. cit.
[291] IBM Business Consulting Services. op. cit., p. 2.
[292] SSA Global Technologies, Inc. loc. cit.
[293] See section 5.1.3.
[294] See section 5.2.1.
[295] IBM Business Consulting Services. op. cit., p. 5.
[296] IBM Global Services. loc. cit.
[297] Roberti, M. 2003. *Analysis: RFID – Wal-Mart's Network Effect*. [Online]. <URL: http://www.cioinsight.com/print_article/0,1406,a=61672,00.asp> Last accessed 24/7/2004.

compared to traditional systems. In addition to this, RFID systems could help lower inventory levels by 10 – 30% and increase sales by 1 – 2% through reduced occurrences of out-of-stock scenarios.[298] [299] Procter & Gamble expects an RFID inventory management system would "free up US$1 billion in working capital and cut inventory carrying costs by over $200 millions per year".[300] Similarly, Boeing believes that when RFID standards have been developed in the airline industry, better inventory management would be possible and would help reduce parts on hand. This is a considerable amount, as parts on hand for some large airlines can "amount to US$1 billion for a single carrier", ultimately saving airlines money.[301]

5.3.4 Security

Whether it is the prevention of general theft in retail outlets, product shrinkage in the middle of the supply chain or the problems associated with authenticating products, RFID technology can aid in securing all phases of SCM. This ability can be largely attributed to the 'always on' and information rich nature of RFID.[302] Furthermore, RFID tags are "virtually impossible to copy", making them suitable to security applications.[303] With the cost of goods 'lost' within the supply chain estimated to "cost European companies 50 million euros a day", securing SCM with RFID technology is paramount.[304]

In this security conscious era, where terrorist attacks are an ever-present threat, there is a great need for stringent security measures, particularly in high-risk supply chains. It is estimated that airlines will "have to spend about $5 billion over the next 10 years to upgrade baggage screening systems to comply with laws passed after 9/11". Many airlines hold the view that RFID can aid in securing their baggage and consumables

[298] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 4.
[299] The Wall Street Journal. loc. cit.
[300] Chandrashekhar, M. 2004. *It fits the bill!*. Businessline. [Online]. Available ProQuest, Document Id: 623937701. Last accessed 10/10/2004.
[301] Brewin, B. 2004. *Delta to test RFID for parts tracking*. Computerworld. [Online]. <URL: http://www.computerworld.com/softwaretopics/erp/story/0,10801,93611,00.html> Last accessed 24/10/2004.
[302] SSA Global Technologies, Inc. loc. cit.
[303] Motorola, Inc. op. cit., p. 1.
[304] Atock, op. cit., p. 23.

supply chain, helping them adhere to the strict new regulations.[305] Allied Business Intelligence notes that although RFID "is only part of a multi tiered approach", the "technology provides unparalleled benefits to an overall solution".[306] The technology could also be used to improve the efficiency and security for all stakeholders at border crossings by authenticating trustworthy organisations that regularly use the crossing.[307]

Theft that occurs in the supply chain is often referred to as 'product shrinkage'. Product shrinkage is rampant, with up to US$30 billion being lost each year, the majority from the middle of the supply chain. Current technologies such as barcodes, do not allow products to be continuously monitored as they progress through the supply chain. This is not the case for RFID and the EPC Network, which allows products to be constantly monitored, alerting SCM systems with specific details in real-time when products go missing, allowing the organisation to take preventative measures in future occurrences.[308]

The International Chamber of Commerce estimates that "counterfeiting now accounts for 8 percent of global trade", making the use of RFID to counter the problem attractive to manufacturers. Tagged products could be traced through the supply chain to ensure they reach their appropriate destinations. Furthermore, the internal manufacturing processes could be secured by placing RFID readers at entrance and exit points.[309] RFID can also provide theft prevention in retail outlets and distribution centres, acting like a "security guard at a gateway".[310] [311] Should a person attempt to remove an item from a store without paying for it, RFID readers can automatically trigger a security alarm.[312] For example, numerous uniforms were being stolen from Star City Casino, so they placed RFID tags inside uniforms to prevent such thefts.[313]

---

[305] Chandrashekhar, loc. cit.
[306] Allied Business Intelligence Inc. 2002. *RFID White Paper*. [Online]. <URL: http://www.dri.co.jp/free/abi_rfid02wp.pdf> Last accessed 26/8/2004. p. 7.
[307] ibid.
[308] VeriSign. loc. cit.
[309] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. loc. cit.
[310] Intermec Technologies, op. cit., p. 2.
[311] Singer, op. cit., p. 6.
[312] Atock, op. cit., p. 25.
[313] Granneman, loc. cit.

5.3.5 Ability to Withstand Harsh Environments

"When environmental issues come in to play, RFID will be a godsend to read".[314] RFID tags are extremely durable and can be read through almost all non-metallic materials. Tags can continue to work flawlessly in harsh temperature conditions, whether it is minus 40 degrees or plus 200 degrees centigrade, and will also survive in most acids.[315] [316] These properties make the technology suitable to a range of new applications not possible with traditional optical barcode technology.[317] This also means that tags can be inbuilt into objects such as wire baskets that can travel through any number of environments.[318] Gerdeman notes that users have been requesting a technology that is not hampered by environmental factors for a long time.[319]

The durability of RFID tags makes them ideal for "dirty, oily, wet, or harsh industrial and commercial environments". The technology can last for extensive periods, often lasting longer than the items they are attached to.[320] Chrysler had attempted using barcodes in its vehicle assembly process, with limited success due to environmental demands.[321] However, as tags can survive very high temperatures and other gruelling demands, their use is common within the automotive industry. Usually, vehicles are exposed to extremely hot environments and require painting as they move along the assembly line. This means that manufacturers can continue to track vehicles regardless of how demanding the manufacturing process is.[322]

Another successful application that takes advantage of the durability of RFID tags is that of Italian pharmaceutical company, Pierrel-Ospedali. Strict and highly regulated quality requirements mean the company has to ensure that some of its products are sterilised for a specific period at very high temperatures. If this step is not correctly completed, then the whole batch of products is destroyed. The company now uses RFID tags to monitor this phase of their manufacturing process to ensure the step is

[314] Interview Participant One, Appendix A1.
[315] Motorola, Inc. op. cit., p. 2.
[316] D'Hont, loc. cit.
[317] SAP White Paper. *Supply Chain Networks.* loc. cit.
[318] Aim Global, loc. cit.
[319] Gerdeman, loc. cit.
[320] Motorola, Inc. op. cit., p. 1.
[321] Finkenzeller, op. cit., p. 4-30.
[322] Aim Global, loc. cit.

completed correctly. A secondary benefit is that the process is more efficient, freeing around 2 to 3 employees typically involved with this step.[323]

5.3.6 Information Properties

The data capacity of RFID tags permits them to very in size, from holding only a few bits to thousands of bits.[324] [325] Tags can have the capacity to store and handle the needs and wants of most users.[326] This data capacity is what makes the identification of individual products feasible.[327] Information properties are also a significant differentiator between RFID and traditional barcode symbologies such as the Universal Product Code (UPC). Tags can hold vast quantities of information, ranging from "an item's serial number, color, size, manufacture data and current price as well as a list of all distribution points the item touched before arriving at a store".[328] In addition to this, tags can be updated on the fly, storing new information from RFID readers as they move across the supply chain.[329] [330] Intermec Technologies cites that the "superiority of RFID over bar codes is undeniable", in terms of its information properties as it is able to "individually identify every product ever manufactured".[331]

5.5 Cost Considerations

5.5.1 Cost Savings

Cost savings through RIFD systems are derived through many of the areas discussed in this chapter, namely labour reduction, enhanced inventory management, advanced security and more efficient management of assets. Previous sections have provided some snapshot estimations of predicted savings as well as some actual savings. Through deploying RFID domestically, it is estimated that the U.S. economy stands to save over US$500 billion annually, solely through RFID's superior inventory

[323] D'Hont, op. cit., p. 7.
[324] Sarma, S., Brock, D., Engels, D. loc. cit.
[325] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 2.
[326] Gerdeman, loc. cit.
[327] Sanford, loc. cit.
[328] Intermec Technologies, op. cit., p. 1.
[329] D'Hont, loc. cit.
[330] Sanford, loc. cit.
[331] Lai, loc. cit.

management capabilities.[332] European companies are set to reap billions of dollars in savings upon RFID's wide acceptance, just through reduced inventory levels.[333]

While the anticipated total savings expected from RFID range significantly, most reports predict that savings will be significant. AMR has estimated that Wal-Mart's supply chain costs are in the vicinity of 10% of all sales. AMR expects Wal-Mart to realise a saving of around 6 – 7% of supply chain costs through the use of RFID, equating to around US$1.4 billion.[334] In contrast to this, New York investment research house, Sanford C. Bernstein & Co. estimates that Wal-Mart "could save nearly $8.4 billion per year when RFID is fully deployed throughout its supply chain and in stores".[335] Both of these forecasts are significant; however, there are large discrepancies between them. This is most likely because the use of RFID across global supply chains is a new concept with limited research. A full breakdown of Wal-Mart's financial savings, as per Sanford C. Bernstein & Co's estimate, is given in the table below.

Table 5.1: Breakdown of Wal-Mart's Projected Savings from RFID

Please see print copy for Table 5.1

(Table adapted from Roberti, M. 2003.[336])

[332] Chandrashekhar, loc. cit..
[333] Atock, op. cit., p. 23.
[334] Shim, loc. cit.
[335] Roberti. *Analysis: RFID – Wal-Mart's Network Effect*. loc. cit.
[336] ibid.

It will be some time before the full potential of RFID is realised, as most applications of the technology in the near future are not expected to be incorporated into the retail shopfront, opting to remain behind the scenes, away from consumers. The widespread use of RFID will grow as the cost of the technology falls, and this will be discussed in subsequent sections.[337] In any case, although RFID is currently expensive, "backers say it offers long-term benefits that could dwarf the impact of the bar code on inventory control and distribution".[338]

5.5.2 Software and Equipment Upgrade Requirements

The integration of RFID will require considerable investment from organisations.[339] Employing the technology will take time as it involves "integrating new technologies with core systems, reengineering business practices and aligning systems with external partners".[340] The process of implementing the technology into existing SCM systems will take time and the cost will encompass all facets of organisations, with the entire process expected to cost millions of dollars.[341]

Wal-Mart has come under fire from many of its suppliers, as it is believed that the cost of compliance with the retailer's mandate will reach US$9 million. Although this figure has been disputed, the Yankee Group has estimated that "consumer goods suppliers will spend an average of US$6.9 million each this year on RFID", close to the US$9 million some Wal-Mart suppliers are claiming.[342] Gartner has indicated that companies should allow a five-year period and US$20 million to integrate RFID technology into current processes.[343] Some parties are concerned that there is a skills shortage in the RFID industry, which will become apparent when the number of firms installing RFID equipment increases.[344] Capital outlays required by RFID are likely to deter the cash strapped airline industry from using the technology in their baggage

[337] Sanford, op. cit., p. 13
[338] RFID Survival. 2004. *RFID and Walmart*. [Online]. <URL: http://www.rfidsurvival.com/RFIDandWalmart.html> Last accessed 18/9/2004.
[339] Interview Participant One, Appendix A1.
[340] IBM Business Consulting Services. op. cit., p. 3.
[341] Sangani, op. cit., p. 24.
[342] Donoghue, loc. cit.
[343] Frontline Solutions. 2004. *Return of RFID investment will require creativity*. [Online]. <URL: http://www.frontlinetoday.com/frontline/article/articleDetail.jsp?id=125499> Last accessed 2/10/2004.
[344] Singer, op. cit., p. 7.

handling systems. Many airline networks span a large number of airports generating significant financial implications.[345] Organisations can decrease their exposure risk and initial outlay by implementing the technology slowly, with small-scale pilots.[346]

5.5.3 Cost of Technology

Presently, RFID technology is expensive and the price of RFID tags has traditionally been a significant obstacle to its widespread deployment in SCM.[347] An Accenture survey found cost to be one of the two primary barriers to the implementation of RFID.[348] The level of investment in RFID technology required to transform current SCM practices was covered in section 5.5.2, and as such, this section will focus on the cost of RFID tags. It should be noted that the price of RFID equipment such as readers would drop as large corporations start manufacturing RFID systems. Following the pricing trend of tags, this would decrease costs while increasing supply.[349]

Reports on the current cost of RFID tags vary, however they all find common ground in noting that the current cost of tags is too high to justify tagging all items.[350] This is why most companies mandating the use of RFID are focusing on tagging pallets and cases, as opposed to item-level tracking, which is years away.[351] Current passive tag cost estimates from Leyden[352], McGinity[353], Sangani[354], Reuters[355], Fontanella[356], Brewin[357] and IBM[358] range from (U.S. currency) 15 cents to 75 cents, with the volume of tags purchased having a significant impact on the final cost.

[345] Berwin, loc. cit.
[346] Donoghue, loc. cit.
[347] The Wall Street Journal. loc. cit.
[348] Accenture. 2004. *High-Performance Enabled through Radio Frequency Identification.* [Online]. <URL: http://www.accenture.com/xdoc/en/services/rfid/capabilities/rfid_maximize.pdf> Last accessed 28/9/2004. p. 7.
[349] Sarma, S., Brock, D., Engels, D. loc. cit.
[350] Fontanella, loc. cit.
[351] Sliwa, loc. cit.
[352] Leyden, loc. cit.
[353] McGinity, M. (No Date). *RFID: Not Your Father's Bar Code*. IEEE Distributed Systems Online. [Online]. <URL: http://dsonline.computer.org/0308/f/newsp.htm> Last accessed 9/9/2004.
[354] Sangani, loc. cit.
[355] Reuters. loc. cit.
[356] Fontanella, loc. cit.
[357] Brewin, loc. cit.
[358] IBM Business Consulting Services. loc. cit.

All reports agree that as RFID technology evolves with ongoing advancements made and production volume increasing, the price will inevitably drop, eventually justifying the business case for tagging all items when tags reach the utopian price of about 1 to 5 cents.[359] [360] Even over the last several years, the cost of tags has fallen significantly, with a tag that cost US$2.35 four years ago, now costing as little as 15 cents.[361] The table below demonstrates the forecast cost of RFID technology.

Table 5.2: Projected RFID Costs

Please see print copy for Table 5.2

(Source: Keith, et. al.)[362]

5.6 Deployment Issues

5.6.1 Manufacturing Sector Concerns

A large portion of the push for RFID uptake is coming from retailers who are forcing manufacturers to absorb the additional costs associated with tagging items and processing the information they generate.[363] Many consumer goods manufacturers are struggling to see any short-term gain from upgrading to RFID technology on their packaging and distribution systems. Consequently, it is being viewed as "the cost of doing business with major customers" such as Wal-Mart, Target, Albertsons and the U.S. Department of Defence, which have mandated that suppliers phase in the use of RFID from 2005.[364]

Some manufacturers are investigating the 'slap and ship' option where they keep their current processes in place. This involves only tagging items as they are shipped, in an

[359] Leyden, loc. cit.
[360] Sliwa, loc. cit.
[361] IBM Business Consulting Services. loc. cit.
[362] Keith, op. cit., p. 11.
[363] Brand, loc. cit.
[364] Brewin, loc. cit.

effort to minimise costs and meet mandate requirements. However, even such minimal approaches can cause problems such as errors with the placement and engineering of tags that need to be readable by customers.[365] 'Slap and ship' also means that the technology will equate to a 100% expense as companies are not even attempting to obtain a return from it. Even manufacturers who opt to use tags to help track their products in the supply chain are not going to see a return on investment (ROI) immediately.[366] Furthermore, Christine Spivey Overby, a senior research analyst at Forrester Research, acknowledges that there "is no business case for most suppliers in the short term".[367] Nevertheless, manufacturers can look forward to seeing a return from RFID over the next few years as uptake of the technology increases.[368] The advantages that RFID offers to organisations are available to companies tagging goods just as much as they are to the companies receiving tagged items.[369]

5.6.2 Requirement of Close Co-operation between Suppliers and Retailers

RFID tags using the EPC standard only contain a serial number. Databases linking these serial numbers to further information are then required to make use of this information. "Data synchronization, integration, transformation, and communication are huge barriers in making the technology work for organizations".[370] Previous endeavours to collaborate across organisations have been unsuccessful as information could not be "readily extracted and shared".[371] All parties are required to collaborate with one another to decipher specifically what information they need and how it should be disseminated.[372]

[365] Albright, loc. cit.
[366] Brewin, loc. cit.
[367] Donoghue, loc. cit.
[368] Brewin, loc. cit.
[369] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 3.
[370] McGinity, loc. cit.
[371] Accenture, loc.cit.
[372] Roberti. *Analysis: RFID – Wal-Mart's Network Effect*. loc. cit.

5.6.3 Lack of Standards

While RFID technology has been around for decades, it has only been recently that its uptake in SCM has been touted. As a result, there is an apparent lack of standards hindering the technology's adoption and support for widespread use in supply chains.[373] [374] [375] Interview participant one noted that as past RFID products have not been a standard technology, they could not be integrated into the supply chain between partners and as such, they do not add value.[376] The development of standards has progressed somewhat through the formation of the EPCglobal network, a member based organisation comprised of numerous large firms funding its operations. However, EPCglobal's standard is yet to be backed by the International Organisation for Standardisation (ISO). As a result, many companies from Europe and Asia as well as several from the U.S., may delay investing in RFID technology for fear their investments may become obsolete once a new standard is agreed upon.[377]

There is still no standard supported by all stakeholders that meets the needs of all users.[378] Incompatible systems exist across different industries, from rail, truck, toll systems, retail and manufacturing. Hence, interoperability is a foremost concern for the seamless use of RFID across supply chains.[379] [380] The EPC standard is of paramount importance to the success of RFID. Ongoing refinements and the backing of numerous multinational organisations mean that it will most likely become the adopted standard in SCM.[381] Another perplexing issue is radio spectrum allocation issues. Radio spectrum is a finite resource and although numerous organisations try to ensure common spectrum management, it is ultimately managed by individual countries. Radio spectrum is used by mobile phones, mobile radio services and radio and television stations, as well as many other services. The fact that RFID requires a radio spectrum allocation further complicates the issue of standardisation in the

[373] IBM Global Services. op. cit., p. 6.
[374] Singer, op. cit., p. 4.
[375] The Wall Street Journal. loc. cit.
[376] Interview Participant One, Appendix A1.
[377] Lai, loc. cit.
[378] Atock, loc. cit.
[379] Sangani, loc. cit.
[380] McGinity, M. loc. cit.
[381] Interview Participant One, Appendix A1.

industry and is poised to be one of the biggest obstacles for omnipresent global RFID standards.[382]

5.6.4 Interference and Reading Considerations

As RFID uses the radio spectrum to transmit its signals, it is susceptible to interference, hindering its ability to transmit clear and reliable information to RFID readers. For example, if a distribution centre was using a nylon conveyor belt, it would cause some radio frequency noise, making it difficult for readers to pick up a tag's data.[383] Similarly, RFID suffers from the inherent range limitations associated with the radio spectrum.[384] [385]

One of the more difficult problems associated with RFID is the positioning of tags on a varying range of products to gain the most successful read rates. Tagging items is not simply a matter of attaching RFID tags. Readers are only able to read tags that are facing a particular way, so items need to be packed accordingly. Tagged items need to be correctly orientated in a standard way that conforms to other supply chain partners' requirements.[386] Ultimately, each product will often have a best place to be tagged, something that will be depend on the material being shipped and is an area that will require extensive testing.[387] Readers are also inhibited by the same environmental factors as tags.[388] Another problem arises when a pallet containing different items is read, as the reader needs to be aware it is reading multiple types of items.[389]

RFID's ability to read through most packaging material such as plastic wraps and cardboard containers is one of its most valuable assets.[390] Metal and liquid have been described as the "kryptonite to RFID" as they can play havoc with RFID signals.[391]

---

[382] Krebs, K. & Michael L. *Global Markets and Applications for Radio Frequency Identification*. 2001. Venture Development Corporation. Natick Massachusetts. [Online]. <URL: http://www.rfidusa.com/pdf/2001-rfid-whitepaper.pdf> Last accessed 3/4/2004. p. 5.
[383] Reuters. loc. cit.
[384] Atock, op. cit., pp. 25 - 26.
[385] McGinity, loc. cit.
[386] Roberti. *Analysis: RFID – Wal-Mart's Network Effect*. loc. cit.
[387] Albright, op. cit., p. 1.
[388] Interview Participant One, Appendix A1.
[389] McGinity, loc. cit.
[390] Zebra Technologies. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. op. cit., p. 2.
[391] McGinity, loc. cit.

Metal that is near a tag or reader has the effect of reducing the "electromagnetic coupling required to transmit energy to the tag" reducing the range of the system.[392] Even a "thin sheet of metal foil can easily block the signal from many tag types", requiring such considerations to be taken into account when planning systems.[393]

Determining the best position for RFID tags can be time consuming, with one company testing six areas on a liquid product, with only one or two of those giving a best read.[394] Procter & Gamble created "RF-friendly" and "RF-unfriendly" product categories, with those containing some form of metal packaging or liquid often making the RF-unfriendly category.[395] The U.S. defence force has suffered from interference problems when tagging their meals ready to eat (MRE) for soldiers. When MRE's were placed in a case, RFID readers were not effectively reading the contents. To work around this, a 'master tag' identifying the contents of the case was attached to the case where it was not affected by interference.[396] These problems are not mortal to RFID as testing and time can overcome such issues.[397] [398]

5.6.5 Privacy Concerns

Privacy issues loom as one of the biggest threats to the unbridled success of RFID. Privacy concerns have the potential to "stop a technology dead in its tracks".[399] Current RFID protocols are designed to offer the most optimal performance between readers and tags, neglecting to address consumer privacy concerns.[400] Privacy advocates are worried that if RFID tags are placed in common items, the product may be tracked once purchased by consumers.[401] Human rights organisations have already raised their disquiet over the technology.[402] In an effort to counter privacy concerns,

[392] Motorola, Inc. op. cit., p. 8.
[393] Singer, op. cit., p. 6.
[394] Albright, op. cit., p. 1.
[395] Brewin, loc. cit.
[396] ibid.
[397] IBM Global Services. loc. cit.
[398] Sliwa, loc. cit.
[399] McGinity, loc. cit.
[400] Floerkemeier, C., Schneider, R., Langheinrich, M. 2004. *Scanning with a Purpose – Supporting the Fair Information Principles in RFID Protocols*. Institute for Pervasive Computing, ETH Zurich, Switzerland. p. 1.
[401] Want, op. cit., p. 84.
[402] Sangani, loc. cit.

the Auto-ID Center has published a paper outlining three fundamental privacy policies for all users of EPC technology.[403]

Clothing retailer Benetton came under fire for placing RFID tags in its clothes. Once the public was made aware of this, consumers called for a boycott against Benetton, causing the retailer to abandon its RFID plans. One of the public's biggest concerns with the plan was that there were no notes on how the tags could be 'turned off' once an item was purchased.[404] Organisations need to market the benefits of RFID to consumers or offer them something back, such as a quicker checkout or discounts for buying tagged items. Consumer concerns can be alleviated through ensuring tags can be deactivated once purchased.[405]

[403] Roberti, M. 2003. *RFID: Mark Benneton on Privacy Woes*. [Online]. <URL: http://www.cioinsight.com/print_article/0,1406,a=61672,00.asp> Last accessed 24/7/2004.
[404] Sanford, loc. cit.
[405] McGinity, loc. cit.

Chapter 6 - Findings

6.1 Introduction

The two preceding chapters of this thesis have utilised an extensive documentation review, supplemented by interviews and small real-world cases to present a thorough overview of the advantages and disadvantages of barcode and radio frequency identification (RFID) technology in supply chain management (SCM). The findings will analyse those two chapters to present the findings of the research. A high-level summary of the advantages and disadvantages will be provided as well as a comparative matrix of common barcode and RFID attributes. The findings will also investigate the adoption of barcodes and the current adoption of RFID and in doing so will identify what the two technologies offer to individual phases of the supply chain and list the numerous representative cases used in the research. In conclusion, the chapter will identify the instigators of barcode technology to find similarities between the development of barcodes and RFID in SCM. This will help tell the likely story of adoption for RFID and provide an insight into the future roles of barcodes and RFID in SCM. Such information will aid organisations in deciding what approach they should take in regards to the adoption of RFID. The likely co-existing relationship of barcodes and RFID will be shown graphically in the adoption fusion curve diagram. For the purposes of this findings chapter, a framework comprising of four supply chain levels will be examined. These levels include the retailer, transport and logistics, warehouse and distribution centres and manufacturers. Accenture uses this framework to display RFID's perceived benefits across the value chain.[406]

6.2 Findings Analysis

6.2.1 The Advantages and Disadvantages of Barcodes and RFID

It is difficult to compare an established and mature automatic identification (auto-ID) technology such as barcodes to an emerging one like RFID. This disparity means that the two technologies are not on level ground, one has had extensive testing in a commercial environment, and the other has limited commercial exposure. Despite this

[406] Accenture, op. cit., p. 5.

inherent limitation, the diagram below lists many of the intrinsic advantages and disadvantages of barcodes and RFID at high-level.

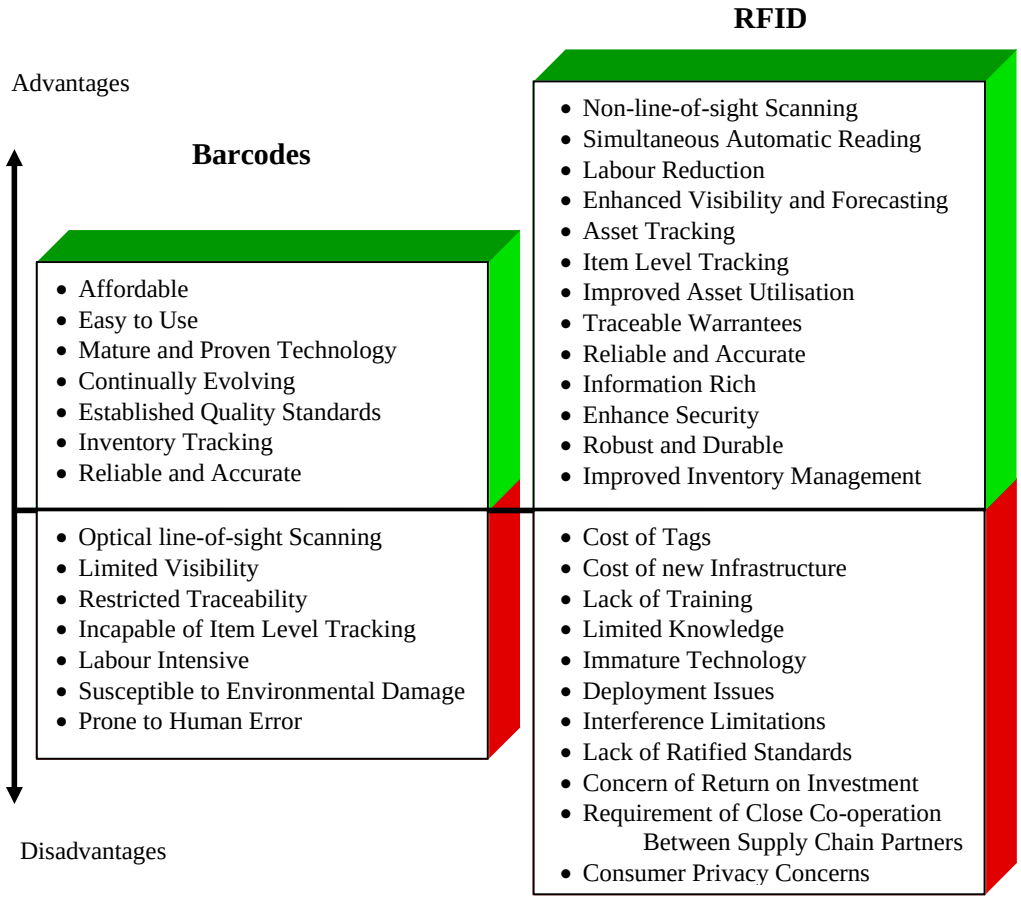


Diagram 6.1: High-level Analysis of Barcodes vs RFID

It should be noted that the diagram offers no weighting to any particular attribute and is not exhaustive; the factors listed have been given the most space in common industry papers and forums. Furthermore, some attributes could be listed as an advantage or disadvantage for both technologies. Where one technology offers a distinct edge over the other, the diagram will list that trait for only the dominant technology. An example of this is asset tracking, which both technologies offer; however, as RFID is superior to barcodes for this purpose, asset tracking is only listed under RFID. The attributes shown are applicable to all parties with a vested interest in SCM. The diagram shows that RFID has a greater number of issues, good and bad when compared to barcodes. This can most likely be attributed to the fact that RFID is an emerging technology. As a result, there is a greater degree of uncertainty surrounding RFID technology with numerous ideas and applications being touted by

RFID stakeholders, many of which are yet to be demonstrated. As RFID becomes more widely accepted and deployed, some factors will abate and others will materialise to become widely accepted. On the other hand, barcodes have been in use for more than 30 years. This has resulted in a high degree of knowledge and certainty about barcodes, which means that the attributes listed are widely accepted. The diagram does show that although RFID has numerous disadvantages, the potential windfall for organisations is superior to that offered by barcodes. In addition, construct validity is demonstrated in that the advantages of RFID generally cater for the disadvantages of barcodes.

6.2.2 Comparative Matrix of Common Barcode and RFID Attributes

This section will provide a comparison of barcode and RFID technology attributes as outlined in chapters 4 and 5. It will summarise this information to provide a high-level snapshot evaluation of the two technologies. These findings are applicable to all organisations, regardless of their positioning in the supply chain. The structure will be based on the layout of chapter 4, with the view of the technologies being established. Consequently, the technical issues, institutional standards, organisational factors and economical considerations will be discussed.

Table 6.1: Technical Attributes

Attribute	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	The radio nature of RFID means tags can be scanned remotely through packaging. It

	often have to be manually manipulated through human intervention.	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.

The technical attributes listed in the above table are a major focal point in current industry discussions. The reason for this is that RFID is still a developing technology, which ensures its technical issues remain a popular and important consideration, as this is the first step in a technology's development. The analysis of barcodes and RFID attributes from a technical viewpoint is quite simple. Although barcodes are a strong performer across the board, RFID is generally on par or superior to barcodes in all technical areas aside from the cost and usability of the technology. The current cost of RFID looms as the technology's biggest inhibiting factor, although it is expected to fall significantly over the next few years. The other main inhibitor to RFID technology is its current lack of institutional standards, which will be examined below.

Table 6.2: Institutional Standards

Barcodes	RFID
Barcodes have established and widely accepted standards that have been critical to their unparalleled success.	While the electronic product code (EPC) is gaining acceptance, RFID still lacks a ratified global standard, hindering the technology's adoption.

Barcodes have a comprehensive range of acknowledged standards that are in use across the supply chain and have been paramount to the success of barcode technology. Of particular importance are the Universal Product Code (UPC) and European Article Numbering (EAN) standards, which are used by millions of companies in more than 140 nations. On the other hand, a lack of standards is one of the major factors inhibiting the further deployment of RFID technology.[407] Barcodes

[407] Accenture, op. cit., p. 7.

have a distinct edge over RFID in this area; however, that is expected, as barcodes are a mature technology. With time RFID standards will be developed and be able to compete with barcode standards on a level playing field. The EPC standard being developed for RFID is gaining momentum and is likely to become the first ratified RFID standard. The EPC is sponsored by many of the world's leading organisations, including Wal-Mart and Procter & Gamble.

Table 6.3: Organisational Attributes

Attribute	Barcodes	RFID
Asset Tracking	Barcodes can be used to track assets, enabling businesses to monitor the use of many investments such as tools.	RFID tags allow organisations to track their assts as they are used. Tags can be attached to returnable items such as beer kegs to help maximise 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, utilising practices such as just in time inventory management.	Once fully deployed, RFID would provide organisations 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 maximise 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 organisations 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 organisations 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.

The table above depicts what barcodes and RFID offer at an organisational level, which, in the case of RFID, will be available once technical and standardisation issues have been solved. Organisational issues are of high importance to companies, as they are the results that they stand to gain from barcodes and RFID. As with the technical attributes, barcodes and RFID provide a similar solution and offer similar advantages; however, RFID outperforms barcodes in all organisational aspects, assuming the

technology is extensively used. This is primarily due to RFID's 'always-on' and item level tracking capabilities.

Table 6.4: Economical Attributes

Attribute	Barcodes	RFID
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 labour 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.
Labour Considerations	Provides a reduction compared to manual data entry, although scanning items still requires a sizable labour contingent.	Automation directly eliminates a substantial labour component from SCM. As the technology becomes more pervasive, further labour 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.

The realisation of financial outcomes occurs last in an auto-ID technology's development and as such, it is being examined last. Table 6.4 above, offers a summary of the economical considerations for barcode and RFID technology. Labour considerations act as a significant differentiating factor in this area as RFID can offer fully automated reading of all tagged items, whereas barcodes generally need some form of manual manipulation and scanning. A flow on effect of this is that RFID is less prone to human error. While the ultimate cost savings of RFID remain an unknown, it is forecasted that the enhanced visibility realised from the widespread deployment of RFID will yield greater returns for companies in the form of better inventory management practices like just in time (JIT). Privacy concerns are an issue that has hampered some RFID rollouts, such as Wal-Mart and Gillette, who planned

the deployment of a trial smart-shelf to monitor customers purchasing some Gillette products. Consumer resentment over the pilot smart-shelf caused Wal-Mart to cancel the trial before it began. Similarly, Benetton faced calls from consumers to boycott the store until it removed the pervasive nature of the RFID tags in its products. In regards to privacy, barcode's technical limitations act as a blessing and negate the possibility of any consumer privacy resentment.

6.2.3 The Story of Adoption

History shows that retailers generally initiate the adoption of an auto-ID technology in the supply chain. Cohen notes, "it was the retail sector that gave the first major vote of confidence to modern auto-ID technologies, particularly the bar code".[408] This is evident when examining Wal-Mart's role in the uptake of barcodes, where the company was one of the instigators and an early adopter of the technology. Unlike barcodes, the adoption of RFID in SCM is at an elementary stage. While the technology is developed and currently available, its uptake in the supply chain will remain in limbo until a common standard is ratified among leading standards organisations. This will most probably be the EPC standard, which has the backing of many of the worlds leading organisations including Wal-Mart and Procter & Gamble. These organisations and numerous others, consisting mainly of large retailers, are instigating much of recent hype surrounding the use of RFID for SCM.

Efficiency is the core reason retailers are pushing the implementation of RFID in supply chains. A large portion of a retailer's expenses come through the expenditure associated with SCM. It is estimated that "Wal-Mart's costs associated with the supply chain, including storing, transporting and keeping track of goods, are about 10 percent of overall sales".[409] Retailers see auto-ID technology, such as barcodes and more recently RFID, as a means to push SCM costs back up the supply chain to manufacturers and logistics companies. For example, with barcodes, retailers have to employee staff to unload stock, manually checking that the contents of each pallet matches the incoming pallet's invoice before adding the stock to the retailer's inventory management system. If the pallet had an RFID tag that stored a list of the

[408] Cohen, op. cit., p. 157.
[409] Shim, loc. cit.

pallets contents, the pallet would just have to pass through an RFID reader and the contents could be automatically checked against the corresponding invoice and added to the retailer's inventory management system. This is just one example; there is a plethora of other advantages for retailers. Ultimately, RFID allows retailers to lower their inventory management costs and improve efficiency. Consequently, large retailers have mandated that that their suppliers deploy new auto-ID technology, which has recently happened with numerous retailers announcing mandates for RFID compliance.

Table 6.5 illustrates the three key phases of the supply chain, to show what barcode and RFID technology offers each. The phases examined are manufacturing, distribution and retailing. The table reveals that RFID offers a larger array of benefits in SCM than traditional barcode technology for all phases. Section 5.6.1 discussed concerns from the manufacturing sector regarding a lack of perceived benefits from RFID, which makes the table's findings more significant as it evident that manufacturers stand to gain more than what barcodes currently offer. This thesis has employed the use of an extensive and diverse sample of real-world case examples to provide factual evidence supporting the documentary research. This ensures that organisations can see the actual effects and experiences they may realise after implementing a barcode or RFID system. Table 6.5 lists these organisations in their respective phase in the supply chain.

Table 6.5: Summary of Individual Supply Chain Phases

	Manufacturer →	Distribution →	Retailer
Barcodes	• Affordable • Accurate and Reliable • Generic quality control • Asset Tracking • Reduced shrinkage • Subject to environmental factors • Labour intensive manual scanning • Non-specific recalls	• Accurate inventory information • Limited visibility • Affordable • Accurate and Reliable • Partial employment of JIT • Labour Intensive • Prone to human error • Susceptible to environmental damage • Better asset management • Time consuming manual scanning	• Inventory Management • Reliable • Labour Intensive • Limited Visibility • Manual stocktakes • Subject to human scanning errors • Slow scanning of incoming shipments
RFID	• Traceable warrantees • Targeted recalls • Better quality control • Enhanced visibility • Security and counterfeiting protection • Increased asset utilisation • Increased labour productivity • Superior WMS • Utilisation of JIT • Better sequencing of WIP materials • Asset tracking • Reduced shrinkage	• Automatic ID of product and pallet contents • Improved order accuracy • Higher order fulfilment • Enhanced Labour Productivity • Enhanced Visibility • Express item picking • Faster put-away times • Theft prevention and enhanced security • Fewer misdirected shipments • Better un/loading times • Superior WMS • Utilisation of JIT • Reduced shrinkage • High-level of automation • Audit trails and route tracking • Asset reduction • Better management of reusable assets • Improved forecasting and planning	• Inventory visibility • Reduced incidence of out-of-stocks • Fewer expired products • Increased labour productivity • Improved customer service • JIT inventory management • Enhanced forecasting • Increased sales • Optimised recalls • Faster unloading times • Increased shipping accuracy • Smart-shelves • Self-checkout • Theft and security enhancement
Representative Examples	• Kimberly-Clark • General Motors • Procter & Gamble • DePuy Orthopaedics • Amcor Fibre Packaging • Colourpoint • MidAmerican Growers • Boeing • Chrysler • Gillette • Pierrel-Ospedali • Oil Refinery (anonymous) • Baking Company (anonymous)	• FedEx • United Postal Service (UPS) • Collex • Online Express Parcels • Delta Airlines • San Francisco International Airport • TrenStar	• Wal-Mart • Benetton • David Jones • Target • Albertsons

In addition to the numerous example organisations listed in the supply chain phases in table 6.5, several barcode and RIFD technology developers were also used in the thesis. These organisations are listed below in table 6.6.

Table 6.6: Representative Examples of Auto-ID Technology Organisations

Organisation
• Nextel Communications • Motorola • Symbol Technologies • Mobiqa • Zebra Technologies

Retailers are in a commanding position that allows them to force suppliers to adopt RFID, as they are the entities that purchase goods from manufacturers. It is in a manufacturer's interest to comply with any mandates as if they do not, and a competitor is willing to comply, then they will lose the business of the retailer. This has the effect of pushing the SCM costs back up the supply chain, from the end to the beginning. Many manufacturers are concerned about the level of investment required to implement RFID systems and are unsure if they will receive a return on their investment. Compounding this concern is the fact that manufacturers have already invested in barcode systems. However, RFID compliant organisations that are utilising the technology's power stand to gain a competitive advantage over rival non-compliant organisations and should not only look to increase efficiency but increase their market share There is no reason why manufacturers, distribution centres and logistics companies cannot achieve the advantages that RFID offers retailers.

6.4 The Future Barcodes and RFID in SCM

While it is impossible to be certain about the future of barcode and RFID technology, examining trends, both past and present, can help to more accurately predict what will happen. It is important that organisations have an insight into how the barcode and RFID relationship will evolve, as there is a considerable amount at stake. Organisations have invested heavily in barcode systems and early adopters of RFID risk wasting large amounts of capital to become RFID compliant if the technology fails to be widely accepted. This thesis has examined the current state of barcode and RFID technology and thoroughly explored each technology's advantages and disadvantages to ascertain what relationship they will have in SCM in the future.

There is no doubt that RFID will play a more dominant role in SCM than it presently does. Diagram 6.1, shows the projected increase in RFID transponder shipments. It illustrates the trend of RFID vastly increasing its use in SCM, from 1% of total transponder shipments in 2002 to 46% in 2007. In addition to this, it shows that the total number of transponders shipped will increase some 500%. This is important to keep in mind when examining the future of RFID in SCM as it demonstrates the growing popularity of RFID as a whole, as well as within the supply chain.

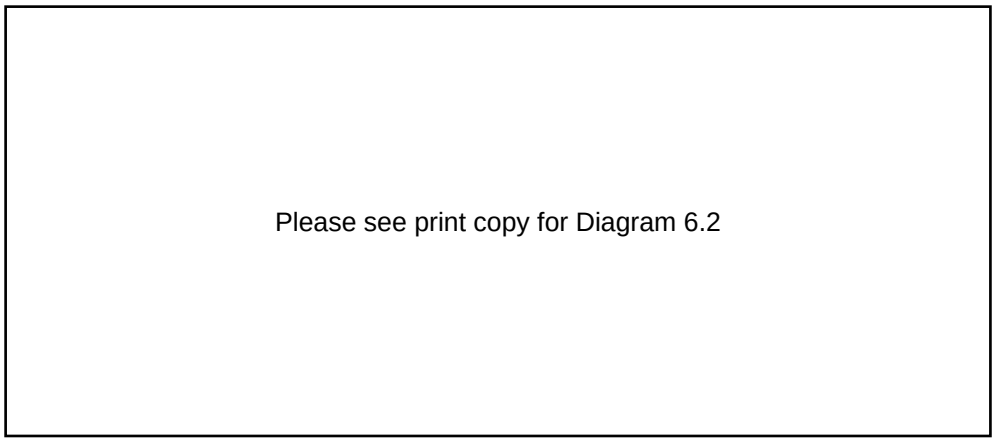


Diagram 6.2: Contribution of RFID Transponder Shipments for SCM in the World Market, 2002 and 2007

(Source: Allied Business Intelligence)[410]

Although Barcodes and RFID share many similar advantages and disadvantages, which were summarised in section 6.2.1, RFID outperforms barcodes in most areas. The similarities of barcodes and RFID enable the two technologies to be used in conjunction. As a result, organisations are in the favourable position of being able to use both of the technologies simultaneously, utilising the inherent advantages of each technology to yield the best result. This ability will lead to a complementary model where barcodes and RFID will co-exist within SCM for quite some time. Diagram 6.2 demonstrates this relationship, through showing the initial uptake of barcodes (in red), followed by a period of co-existence (in yellow) and finally the total dominance of RFID (in blue). This pattern is already evident within the SCM industry as recent

[410] Allied Business Intelligence Inc, loc. cit.

retailer mandates currently only require suppliers to tag items at a pallet level, opting to continue using barcodes for item level tacking.

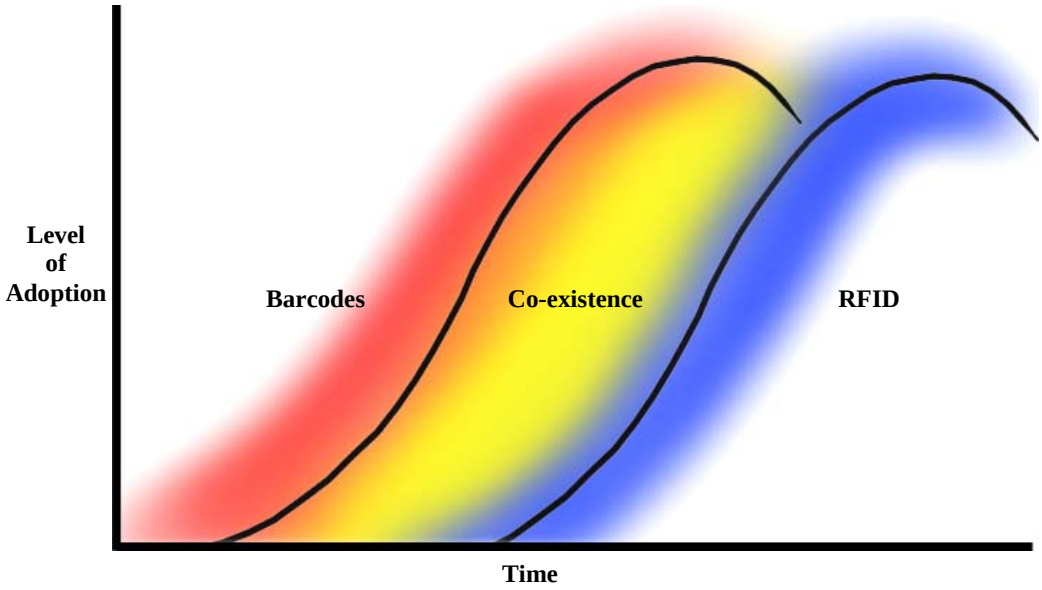


Diagram 6.3: The Barcode and RFID Adoption Fusion Curve

Chapter 7 - Conclusion

7.1 Overview

The purpose of this thesis was to examine barcode and radio frequency identification (RFID) technology in supply chain management (SCM), with a view to explaining the advantages and disadvantages of the two auto-ID technologies. Information was gathered through several interviews and an extensive analysis of past research and documents. The research also identified the drivers for barcode and RFID deployments and recognised the significance of a ratified RFID standard. In doing this, the thesis acknowledged that barcodes and RFID would likely co-exist in SCM for quite some time.

7.2 Principal Conclusions

There will always be different automatic identification (auto-ID) technologies on the market with several being used in conjunction for SCM purposes. Barcodes will continue to play a significant role in supply chain management, whether it is helping a supplier streamline their inventory management practices or at the checkout of a supermarket. However, due to the inherent advantages of RFID technology, such as not requiring line-of-site and the ability to track products in real-time, RFID will be increasingly utilised in SCM. It is predicted that this will lead to a co-existence of the two technologies, where they will play a complementary role to each other. Organisations will able to leverage the power of barcodes and RFID to achieve new levels of efficiency both internally and with partners.

There is an evolutionary paradigm in the adoption of auto-ID technology for SCM, in that retailers act as the instigators of new technology. This was the case for barcodes and is proving to be the case with RFID.[411] Pressure from retailers leads to a 'push and pull' effect whereby retailers force suppliers to adopt new technology with the technology being pulled back up the supply chain, from manufacturers, logistics, distribution centres and retailers. Organisations are integrating RFID into their supply chain to meet either mandate requirements or when the return on vestment is justified

[411] Cohen, loc. cit.

it. The emergence of RFID standards such as the Electronic Product Code (EPC) will facilitate this process. Furthermore, there is a relationship between the cost of RFID and the technology's level of usage, whereby as the cost of RFID decreases, its level of usage throughout the supply chain will increase.

7.3 Implications of Findings

The results of this thesis are relevant to all organisations dealing with SCM, and in particular those using or considering the use of barcode and/ or RFID technology. Recently, a number of the world's largest retailers and government organisations such as Wal-Mart and the U.S. Department of Defence introduced mandates for RFID adoption. As the use of RFID for widespread SCM applications is relatively new and undocumented with only a limited number of RFID deployments, many businesses are unsure what they stand to gain. Compounding this issue is the fact that most large organisations have invested heavily in barcode systems and are sceptical about RFID technology. This thesis provides a thorough summarisation of the advantages and disadvantages of the two technologies within a SCM context. It also examines the technologies at key points in the supply chain, providing information that is specific for manufacturers, distribution centres, logistic companies and retailers. The findings, which offer insight into the adoption pattern of barcodes and RFID in SCM, will clarify to organisations what they stand to gain and lose. Through achieving this, the research will help guide organisations in deciding what adoption strategy most suits their case.

7.4 Research Scope

This thesis has filled the void of research exploring the advantages and disadvantages of barcode and RFID technology for SCM purposes. To achieve this, the research used an extensive analysis of previous research and used a mix of academic and industry based papers. While the number of academic papers relating to the thesis is scant, there is an abundance of industry level papers. The vast number of industry papers used throughout the thesis serves to strengthen the validity of the research and findings. Additionally, numerous real-world case examples, as listed in section 6.2.3,

were used throughout the thesis ensuring that the findings are relevant to organisations.

7.5 Limitations and Further Research

There are a number of inherent limitations within the context of this thesis. First, the timeframe and size limitations of an honours thesis did not permit the inclusion of a broad stakeholder analysis. Such analysis would have allowed the research to first identify and second address, specific industry and stakeholder concerns. Information for this analysis could be in the form of a wide-ranging stakeholder survey. While this did not hinder the research and findings of the thesis, it would be deemed a worthy inclusion.

Second, as the thesis was exploring high-level issues, it was not necessary to undergo a thorough quantitative analysis. A quantitative analysis would have provided more sound findings through exploring real-world experience of barcode and RFID deployments and included detailed financial and managerial details. Such information would have allowed the findings to more accurately differentiate barcodes and RFID at individual attribute levels. To counter this issue, a large number of mini-cases were used throughout the thesis, which further validated its findings and relevance to the SCM industry.

Third, chapter 5, only briefly discussed the issue of privacy with RFID. Privacy concerns loom as one of the greatest threats to the unrivalled success of RFID, as shown when examining Benetton's experience in section 5.6.5. There is a lack of research in this important field and an honours thesis does not have sufficient scope to cover this issue.

7.6 Recommendations

Barcode technology has been used in SCM for more than three decades and during this time, it has proved successful in most areas of SCM. The technology has a comprehensive infrastructure, numerous global standards and continues to reinvent

itself for use in new applications.[412] Consequently, there is no doubt that barcodes will remain a prominent auto-ID solution for the foreseeable future. However, in an increasingly competitive corporate environment, organisations are turning to their SCM practices to yield new levels of efficiency and attempt to gain, not only cost reductions through improved SCM, but also a competitive edge and improve their market share.

This continual pursuit by the world's leading organisations has accelerated the rise of RFID and thrust it into the limelight. When Wal-Mart, the world's largest retailer, introduced a mandate for RFID compliance, many competitors followed suit and jumped on the bandwagon for fear of being left behind. This rapid rise of RFID technology has served to highlight the apparent lack on information and knowledge available to organisations investigating the differences of barcode and RFID technology in SCM. There is also only limited information of how the relationship of two auto-ID technologies will develop.

After analysing the research and findings, it is recommended that if organisations have any interest in SCM, they should consider deploying RFID. Those implicated by one of the many mandates should endeavour to comply as soon as possible. Although there are contrasting opinions in relation to when organisations will receive a return on RFID investments, all literature indicates that there are savings to be achieved. However, before investing in RFID, entities need to make certain any deployment is future proofed ensuring that it is compatible with any developments to the EPC standard, which is expected to become the ratified standard. It is important that organisations continue to utilise and maintain their current barcode systems. It will be a long time before RFID replaces barcodes altogether, instead the technologies will 'converge' or 'coexist' so that organisations can yield the power of both to achieve new levels SCM efficiency. As entry barriers diminish, the technology will become more widespread, further lowering the cost of RFID.

[412] See section 4.1.3

BIBLIOGRAPHY

Accenture. 2004. *High-Performance Enabled through Radio Frequency Identification*. [Online]. <URL: http://www.accenture.com/xdoc/en/services/rfid/capabilities/rfid_maximize.pdf> Last accessed 28/9/2004.

Adams Communications. 2002. *Barcode History Page*, [Online] <URL: http://www.adams1.com/pub/russadam/history.html> Last accessed 7/3/2004.

Aim Global. (No Date). *RFID – Common Applications*. Association for Automatic Identification and Mobility. [Online]. <URL: http://www.aimglobal.org/common_applications_rfid.asp> Last accessed: 15/9/2004.

Albright, B. 2004. *RFID Tag Placement*. [Online]. <URL: http://www.frontlinetoday.com/frontline/article/articleDetail.jsp?id=98552> Last accessed 7/9/2004.

Allied Business Intelligence Inc. 2002. *RFID White Paper*. (Online). <URL: http://www.dri.co.jp/free/abi_rfid02wp.pdf> Last accessed 26/8/2004.

Anderson, T. & Kanuka, H. 2003. E-research: methods, strategies, and issues, Allyn and Bacon, Boston.

Atock, C. 2003. *Where's My Stuff?*. Manufacturing Engineer, April.

Automatic I.D. News Asia. 1998. *Alto Group hits high notes with new inventory management system*. March/April.

Automatic I.D. News Asia. 1998. *RF cuts processing time for Lexus car and parts deliveries*. August/September. pp. 30 – 34.

Boone, C. 2003. *Industry Developments and Models: The RFID Ecosystem for the Retail Supply Chain*. IDC, Framingham.

Brand, J. 2004. *RFID: Why business wants it*. Interview with Richard Aedy. The Buzz. ABC. Transcript available online <URL: http://www.abc.net.au/rn/science/buzz/stories/s1054968.htm> Last accessed 28/2/2004.

Brewin, B. 2003. *Army to test passive RFID tags on food shipments*. Computerworld. [Online]. <URL: http://www.computerworld.com/softwaretopics/erp/story/0,10801,87623,00.html> Last accessed 24/10/2004.

Brewin, B. 2003. *Delta Says Radio Frequency ID Devices Pass First Bag-Tag Test*. Computerworld. [Online]. <URL:

http://www.computerworld.com/printthis/2003/0,4814,88446,00.html> Last accessed 26/9/2004.

Brewin, B. 2004. *Consumer packaged goods firms: No quick ROI from RFID*. Computerworld. [Online]. <URL: http://www.computerworld.com/printthis/2004/0,4814,91797,00.html> Last accessed 26/9/2004.

Brown, S. A. 1997. *Revolution at the Checkout Counter: the explosion of the bar code*, Harvard University Press, London.

Burnell, J. 1998. *Technology Tames Logistics – Matching information flow to material flow is key to benefits in logistics and supply chain management programs*. May/June. Automatic I.D. News Asia.

Chandrashekhar, M. 2004. *It fits the bill!*. Businessline. [Online]. Available ProQuest, Document Id: 623937701. Last accessed 10/10/2004.

Cohen, J. 1994. *Automatic Identification and Data Collection Systems*, McGraw-Hill Book Company, London.

Collins, D. J. & Whipple, N. N. 1994. *Using Bar Code- Why It's Taking Over*, Data Capture Institute, Massachusetts.

Crowe, D. 2004. *DJs to upgrade for faster service.* The Australian Financial Review. p. 53.

Crowe, D. 2004. *Tag Technology coming of age, and sheep are leading the way*. Special Reports – The New Supply Chain. The Australian Financial Review. p 8.

CSX World Terminals, LLC. 2001. [Online] <URL: http://www.csxworldterminals.com/Resources/Glossary.asp?s=s>. Last accessed 11/3/2004.

D'Hont, S. (NO DATE). *The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution*. Texas Instrument TIRIS. Whitepaper. [Online]. <URL: http://www.ti.com/tiris/docs/manuals/whtPapers/manuf_dist.pdf> Last accessed 27/8/2004.

Dirks, B. 2003. *Point-of-sale software: A managerial goldmine*. CPA Software News, Shawnee, Vol.13, Iss. 4; pg. 24. [Online]. Available ProQuest, Document ID: 377240051. Last accessed 12/10/2004.

Donoghue, A. 2004. *RFID: Proceed with caution*. ZDNet. [Online]. <URL: http://www.zdnet.com.au/insight/hardware/0,39023759,39147123,00.htm> Last accessed 27/9/2004.

Edquist, C. 1997. *Systems of Innovation*. Redwood Books, Great Britain.

EPC Global Inc. 2003. [Online] <URL: http://archive.epcglobalinc.org/aboutthecenter.asp> Last accessed 11/3/2004.

EPCglobal, Inc. 2003. [Online], <URL http://www.epcglobalinc.org/about/faqs.html#6> Last accessed 11/3/2004.

Evans, P. & Wurster T. 1997. *Strategy And The New Economics of Information*. Harvard Business Review, 75 (Sept – Oct): pp. 70 – 82.

Finkenzeller, K. 2001. RFID Handbook: radio-frequency identification fundamentals and applications, John Wiley & Son, New York.

Floerkemeier, C., Schneider, R., Langheinrich, M. 2004. *Scanning with a Purpose – Supporting the Fair Information Principles in RFID Protocols*. Institute for Pervasive Computing, ETH Zurich, Switzerland.

Fontanella, J. 2003. *Wal-Mart Pulls RFID Trigger: The Race Is On*. AMR Research. [Online] <URL: http://www.amrresearch.com/content/DisplayPDF.asp?pmillid=16268&strMasterType=alert> Last accessed: 22/4/2004.

Foster, P. 2004. *San Francisco Airports RFID baggage handling system*. R.F.I.D World Sydney. Aviation Security Manager, San Francisco International Airport.

Frontline Solutions. 2004. *Return of RFID investment will require creativity*. [Online]. <URL: http://www.frontlinetoday.com/frontline/article/articleDetail.jsp?id=125499> Last accessed 2/10/2004.

Geers, R. 1997. Electronic Identification, Monitoring and Tracking of Animals. CAB International, United Kingdom.

Gerdeman, J. D. 1995. Radio Frequency Identification Application 2000: a guide to understanding and using radio frequency identification. Research Triangle Consultants, North Carolina.

Granneman, S. 2003. *RFID Chips Are Here.* The Register. [Online]. <URL: http://www.theregister.co.uk/content/archive/31461.html> Last accessed 21/3/2004.

Grieco, P. T, et. al. 1989. *Behind Bars: bar coding principles and applications*, PT Publications, Florida.

Grubb, S., et. al. *Radio Frequency Identification*. Purdue University. [Online]. <URL: http://www.tech.purdue.edu/graduate/courses/Tech621aw/Rfid.pdf> Last accessed: 2/4/2004.

Heinen, MG, Coyle, GA, Hamilton, AV. 2003. *Barcoding makes its mark on daily practice*. Nursing Management, October. p. 18. [Online]. Available ProQuest, Document ID: 442886571. Last accessed 17/10/2004.

Heng, Q. 1998. *Bar coding on cellular phones helps Motorola perfect online tracking*. Automatic I.D. News Asia. October/November. pp. 23 – 24.

Huhns, M., Stephens, L & Ivezic, N. 2002. *Automating Supply-Chain Management*. Available ACM Press. Last accessed: 1/4/2004.

IBM Business Consulting Services. 2004. *Streamlining the supply chain using radio frequency identification*. IBM Whitepaper. [Online]. <URL: http://www-1.ibm.com/services/us/bcs/pdf/g510-3839-streamlining-supply-chain-using-radio-frequency-identification.pdf> Last accessed 27/9/2004.

IBM Global Services. 2004. *Beyond the bar code: Transforming business with Radio Frequency Identification*. IBM Corporation. [Online]. <URL: http://www-1.ibm.com/industries/wireless/doc/content/bin/Beyond_the_Barcode.pdf> Last accessed 1/10/2004.

Intermec Technologies, 2002. *RFID Technology In Retail*. White Paper.

Keith, A. et. al. 2002. *Focus on the Supply Chain: Applying Auto-ID within the Distribution Center*. IBM Business Consulting Services. Auto-ID Center, Massachusetts Institute of Technology.

Kevan, T. 2004. *Improving Warehouse Picking Operations*. Frontline Solutions. [Online]. Available ProQuest, Document ID: 639486161. Last accessed 11/10/2004.

KPMG Consulting. 2001. *Lessons in Supply Chain Management From 2001: The Imperfect Crime*. 'Supply Chain White Paper'.

Krebs, K. & Michael L. 2001. *Global Markets and Applications for Radio Frequency Identification*. Venture Development Corporation. Natick Massachusetts. [Online]. <URL: http://www.rfidusa.com/pdf/2001-rfid-whitepaper.pdf> Last accessed 3/4/2004.

Kumar, K. 2001. *Technology for Supporting Supply Chain Management*. 'Communication of the ACM', Vol. 44. No. 6. pgs58-61. [Online]. Available ACM Press. <URL: http://doi.acm.org/10.1145/376134.376165> Last accessed 15/3/2004.

Lai, E. 2004. *RFID Revolution is still just a promise*. American City Business Journals, September. [Online]. Available ProQuest Database, Document ID: 693337261. Last accessed 10/10/2004.

LaMoreaux, R D. 1998. *Barcodes and Other Automatic Identification Systems*, Pira International, New York.

Lawson, M. 2004. *Technology is reshaping the industry*. Special Reports – The New Supply Chain. The Australian Financial Review. pp. 2 – 3.

Leyden, J. 2004. *European retailers have the hots for RFID*. The Register. [Online]. <URL: http://www.theregister.co.uk/content/53/35214.html> Last accessed 21/3/2004.

Library of Automation 2003. [Online] <URL: http://www.libraryhq.com/glossary.html#B> Last accessed 16/3/2004.

Long, CJ., Grieco, PL., and Gozzo, MW. 1989. *Behind Bars: bar coding principles and applications*, PT Publications, Florida.

Masters, A. 2003. *Humancentric Applications of RFID: The Current State of Development*. Bachelor Honours Thesis, University of Wollongong.

McGinity, M. (No Date). *RFID: Not Your Father's Bar Code*. IEEE Distributed Systems Online. [Online]. <URL: http://dsonline.computer.org/0308/f/newsp.htm> Last accessed 9/9/2004.

McNermey, G. 2003. *Companies are struggling with where to start using RFID to enhance their supply chains*. AMR Research. [Online]. Computer Weekly <URL: http://www.computerweekly.com/Article119659.htm>. Last accessed 7/3/2004.

Meyers, R. 2000. *The ten commandments of bar coding*. Frontline Solutions, August, pp. A-5- A-22.

Michael, K & Masters, A. 2004. *Applications of Human Transponder Implants in Mobile Commerce*. University of Wollongong.

Michael, K. 2003. *The Auto-ID Trajectory*, PhD Thesis, University of Wollongong.

Mills, K. 2004. *Tags weigh in for landfill trucks*. The Australian, IT Business.

Minichiello, V. Aroni, R. Timewell, E. Alexander, L. 1995. *In-depth Interviewing*, 2nd edition, Longman, Melbourne.

Modern Materials Handling. 1996. *Linerless label printing: New technology with proven savings*. Vol.51, Iss. 14; pg. S22, 1 pgs. [Online]. Available ProQuest, Document ID: 10468438. Last accessed 11/10/2004.

Moore, B. & Albright, B. 1998. *EAN/UCC create new item marking symbologies*. August/September. Automatic I.D. News Asia. pp. 24 – 25.

Motorola, Inc. 1997. Electro-Magnetic RFID: Everything You Need to Know About Inductively coupled RFID. Whitepaper.

Mullin, E. 2002. *Electronic Product Code*. Baseline, Ziff Davis Media Inc. [Online] <URL: http://www.baselinemag.com/article2/0,3959,655991,00.asp> Last accessed 16/3/2004.

New Jersey Business & Industry Association. 2004. *The Bar Code Hits 30*. [Online]. Available ProQuest Database, Document ID: 688692901. Last Accessed 10/10/2004.

Palagyi, S. 1999. *Six steps toward supply chain optimization*. June, Automatic ID News Asia.

Palmer, R. C. 1995. *The Bar Code Book- Reading, Printing and Specification of Bar Code Symbols*, Helmers Publishing Inc., New Hampshire.

Palmer, R. C. 1995. *The Bar Code Book: Reading, Printing and Specification of Bar Code Symbols*, Helmers Publishing Inc., New Hampshire. Third Edition.

Reuters. 2004. *Wired News: Wal-Mart, DOD Forcing RFID*. [Online]. <URL: www.wired.com/news/print/0,1294,61059,00.html> Last accessed 18/9/04.

RFID Journal. 2004. *Frequently Asked Questions*. [Online]. <URL: http://www.rfidjournal.com/article/articleview/anchor#002> Last accessed: 1/4/2004.

RFID Survival. 2004. *RFID and Walmart*. [Online]. <URL: http://www.rfidsurvival.com/RFIDandWalmart.html> Last accessed 22/7/2004.

Roberti, M. 2003. *Analysis: RFID – Wal-Mart's Network Effect*. [Online]. <URL: http://www.cioinsight.com/print_article/0,1406,a=61672,00.asp> Last accessed 24/7/2004.

Roberti, M. 2003. *RFID: Mark Benetton on Privacy Woes*. [Online]. <URL: http://www.cioinsight.com/print_article/0,1406,a=61672,00.asp> Last accessed 24/7/2004.

Sanford, V. 2003. Pervasive Computing Goes the Last Hundred Feet with RFID Systems. IEEE CS and IEEE ComSoc, April-June.

Sangani, K. 2004. *RFID Sees All*. IEE Review, Volume 50, Issue 4, April.

SAP AG. 2004. *Putting RFID on the Fast Track*. [Online]. <URL: http://www.sap.com/solutions/business-suite/scm/rfid/brochures/index.aspx> Last accessed 28/9/2004.

SAP White Paper. 2002. *Supply Chain Networks*. Online. <URL: http://www.sap.com/solutions/scm/brochures/ note: no direct link available>. Last accessed: 4/3/2004.

Sarma, S., Brock, D., Engels, D. 2001. *Radio Frequency Identification and The Electronic Product Code*. MIT Auto-ID Center. IEEE Micro.

Savi Technology. 2002. *Active and Passive RFID: Two Distinct, But Complementary, Technologies for Read-Time Supply Chain Visibility*. [Online]. <URL: http://www.savi.com/solutions/whitepapers/RFID_whitepaper.pdf> Last accessed: 5/3/2004.

Shim, R. 2003. *Wal-Mart to throw its weight behind RFID*. CNET News. [Online]. <URL: http://news.com.com/2102-1022_3-1013767.html> Last accessed 26/8/2004.

Singer, T. 2003. *Understanding RFID – A Practical Guide for Supply Chain Professionals*. Tompkins Associates. [Online]. <URL:

http://www.tompkinsinc.com/publications/monograph/monographList/WP-15.PDF> Last accessed 23/3/2003.

Sliwa, C. 2003. *RFID Tags Gat Cheaper*. Computerworld. [Online]. <URL: http://www.computerworld.com/printthis/2003/0,4814,84004,00.html> Last accessed 26/9/2004.

Softchain. 2002. *Improving Extended Supply Chain Performance Through Better Control*. [Online]. <URL: http://www.manufacturing.net/scm/contents/pdf/softchain_wp.pdf>. Last accessed 1/3/2004.

SSA Global Technologies, Inc. 2004. *Get ready for real-time supply chain visibility*. [Online]. <URL: http://www.ssaglobal.com/scm/rfid.pdf> Last accessed 28/9/2004.

Stephenson, C. 1998. *Get a grip with auto ID [Warehouse management systems]*. Canadian Transportation Logistics. Vol.101, Iss. 9; pg. 24. [Online]. Available ProQuest, Document ID: 390771981. Last accessed 12/10/2004.

Swartz, J. 1999. *The growing 'MAGIC' of automatic identification*, IEEE Robotics & Automation Magazine, pp. 20-22, 56.

Symbol Technologies. 2004. *PSM20i Bar Code Scanning Module for Motorola iDEN Phones*. [Online]. <URL: http://www.symbol.com/products/barcode_scanners/barcode_psm20i.html> Last accessed 12/10/2004.

Teresko, J. 2003. *Winning with wireless*. Industry Week, Vol.252, Iss. 6; pg. 60. [Online]. Available ProQuest, Document ID: 345556831. Last accessed 12/10/2004.

The Wall Street Journal. 2004. *Retailers in race for wireless chip*. The Australian Financial Review. p 68.

Thompson, N. 2003. *RFID and barcodes may co-exist for now*. American Printer, Vol.231, Iss. 6; pg. 58. [Online]. Available ProQuest, Document ID: 421309991. Last accessed 11/10/2004.

United States Department of Health and Human Services. 2003. *Secretary Thompson Announces Steps to Reduce Medication Errors: FDA Proposals for Medication Bar Coding and Safety Reporting Will Improve Patient Safety*. [Online]. <URL: http://www.os.hhs.gov/news/press/2003pres/20030313.html> Last accessed 17/10/2004.

Varchaver, N. 2004. *Scanning the Globe*. Fortune, New York. Vol.149, Iss. 11; pg. 144, 5 pgs. [Online]. Available ProQuest, Document ID: 643106141. Last accessed 10/10/2004.

VeriSign. 2004. *The EPC Network: Enhancing the Supply Chain*. 'VeriSign White Paper'. [Online]. <URL:

http://www.verisign.com/nds/directory/epc/epc_whitepaper.pdf> Last accessed 1/3/2004.

Vernon, M. 2003. *Don't count out barcodes just yet: Teaching an old technology new tricks*. [Online]. <URL: http://msnbc.msn.com/id/3606439/> Last accessed: 2/4/2004.

Want, R. 2004. *Enabling Ubiquitous Sensing with RFID*. Invisible Computing April, Intel Research. [Online]. <URL: http://www.computer.org/computer/homepage/0404/invisible/r4084.pdf> Last accessed 8/9/2004. pp. 84 – 86.

Williamson, H. 2002. *Research methods for students, academics and professionals*. 2nd Edition. Quick Print, Wagga Wagga.

Wind, G. 2004. *Creating business intelligence from what were black holes of information and data*. R.F.I.D. World Sydney. Amcor Fibre Packaging.

Wu, J., et al. 2000. *Supply Chain Management Systems: State Of The Art And Vision*. Department of Mechanical and Manufacturing Engineering, The University of Calgary, Calgary Canada.

Zebra Technologies. (No Date). *The Basics of Bar Coding*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/BarcodingBasics200111.pdf> Last accessed 28/9/2004.

Zebra Technologies. 2002. *Bar Coding ROI in Mail Order Fulfillment and Distribution Centers*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/ROI_Mail_whitepaper.pdf> Last accessed 1/10/2004.

Zebra Technologies. 2003. *Bar Codes and Manufacturing*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/BarCodesManufacturing.pdf> Last accessed 28/9/2004.

Zebra Technologies. 2003. *Bar Coding 101… What You Need to Know*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/11441Lr2-BarCoding101.pdf> Last accessed 29/9/2004.

Zebra Technologies. 2003. *Enterprise-Wide Data Collection and Bar Code Printing for Superior Supply Chain Management*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/13031Lr1-SupplyChainMgmtWP.pdf> Last accessed 1/10/2004.

Zebra Technologies. 2004. *Bar Coding and RFID: The Key to Traceability and Safety in the Foodservice Supply Chain*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/WP13455LfoodService.pdf> Last accessed: 22/3/2004.

Zebra Technologies. 2004. *RFID: The Next Generation of AIDC* [Application White Paper]. [Online]. <URL:

http://www.zebra.com/whitepapers/11315Lr2RFIDTechnology.pdf>. Last accessed: 3/3/2004.

Zebra Technologies. 2004. *Zebra's RFID Readiness Guide: Complying with RFID Tagging Mandates*. Application White Paper. [Online]. <URL: http://www.zebra.com/whitepapers/WP13467Lreadiness.pdf> Last accessed 29/9/2004.

Appendix

A1 – Interview One

Participant's Organisation Positioning - Barcode and RFID Technology Vendor

Interviewer – What is does your job involve?

Participant 1 – I am a systems engineer, that means I am tech support for the sales guys, so basically we've got presales and post sales. I am involved in the presales activity, so I do tech support when we are developing a solution and in a pilot. Once that solution has been validated, tested and verified, I hand that off to the support people who will start replicating it and applying it out in the field.

Therefore, if someone buys 2 or 3 of our rugged PDAs, I will help through the pilot period, work with the guys who do the software and integrate it. Once they have given approval, I will document what needs to be done and hand it off to the support.

Interviewer – Do you mainly deal with barcodes or do you also deal with RFID?

Participant 1 – My organisation's story now is capture, move and manage. We have been around in bar coding for more than 20 years and we've also been with wireless for around about 15 years. We were doing wireless networking before 802.11 was the standard. The problem is we don't have so much mind share in terms of marketing; we have a lot of market share, just not much mind share.

We do capture, move and manage. Capture with point of sales (POS) barcode scanners, rugged personal digital assistant (PDA) like you see the couriers carrying, etc. We do wireless networking infrastructure for the move part and we do the management tools. We have a web based platform where if you've got a PDA in your warehouse, it lets you drill down into that PDA, what the persons doing on it, how many scans they're doing, battery levels, if they're running any games, etc, letting you manage the device as well.

So what we're looking at is, we've always been at the forefront of data capture and we see RFID as just another form of data capture.

Interviewer – I've read that your company has just purchased a leading RFID technology manufacturer. How will your organisation fit RFID technology into its product and service offerings?

Participant 1 – That will be interesting, we can't really plot out how that is going to integrate into our business, but the bottom line is that RFID is going to be a really important part in the long term. I think that early next quarter we are planning on releasing some products which will be co-branded.

Interviewer – A number of people are predicting that barcode and RFID technology will be co-existing for quite some time, is that how you think the market will evolve?

Participant 1 – The RFID manufacturer we purchased has been around for a long time and they have put a lot of effort into developing where and what they have, so I don't see my company actually destroying their brand.

Interviewer – I'd just like to discuss a few of the common barcode applications that your organisation offers in relation to SCM, whether it be in manufacturing or logistics etc.

Participant 1 – From a supply chain perspective, we try to get involved in as many steps as possible, so in warehouses, distribution centres, guys in trucks, right the way through to the POS. Obviously this means that we have to deal with different customers the whole way along.

Participant shows an RFID diagram of the SCM process

That shows pretty much the whole SC. We don't actually do barcoding, we just do the technology that allows you to read it. So we'll have scanners at manufacturers warehouses to do inventory and stock control, work in progress, completed work, stock out and the like. In the transport and logistics chain, proof of delivery, data capture through that and receipting.

Interviewer – So all that would lead to things like lowering costs through labour reduction and the like?

Participant 1 – Yes, the big thing is inventory control and labour reduction isn't so much of a driver, it is more about efficiency rather than recording things by paper which leads to things such as JIT inventory control. That is where RFID and the EPC chain is going to really add even more value than barcoding in some places.

So we have mobile data terminals which have historically been dos based, however we have recently move to Windows CE and Windows mobile. So they will be used for example in a car spare parts warehouse doing pick lists. This is where they receive a list of parts that need to be sent out from the warehouse to all the service centres around Australia. So they can download the pick list to this device, go round the warehouse and be told where to go next, scan the item out of the bin and place it in their pick tray and then ship it out.

Interviewer – So this would lead to a reduction in errors?

Participant 1 – Yes, exactly, it destroys human error and if there is no stock then it [the system] can create a replenish order in the inventory straight away.

Interviewer – Would customers, of suppliers also benefit as well, as a result of the higher availability of inventory?

Participant 1 – Absolutely, and then right the way through, with your T and L guys, scanning onto a truck, scanning off a truck to the retailer at the POS. So back dock receiving, stock control, stock counts and stock take.

Interviewer – To what extent does your organisation work with the UPC standard?

Participant 1 – Yes, the UPC/EAN is the dominate standard in retail. All of our scanners read all codes, as much as possible. Obviously, we can't do the 2D barcodes on some of the scanners. However, all of our scanners do the UPC, EAN, some of the lesser used ones. All of them do SSCC, the various shipping standards.

Interviewer – So some of your scanners do scan 2D barcodes?

Participant 1 – Yes, however there is not a lot of uptake in 2D barcoding in Australia. We are probably going to see a little bit of surge in what we call RSS, which is a Reduced Space Symbology barcode. This involves taking one UPC barcode, shrinking it down and placing another one on top of it. So you will be able to individual labelling for items like apples and oranges and scan them through at the POS.

Interviewer - So this allows for the tracking of individual items using barcodes?

Participant 1 – Yes

Interviewer – So you think that RSS will be turn out to be the most used in Australia?

Participant 1 – Don't know, it is going to be sort of parallel to RFID in some way.

Interviewer – I am trying to ascertain what role the UPC standard will have in the future.

Participant 1 – It is going to have a continuing role. There are hundred and thousands of major and minor retailers across the world who have already invested in barcode scanning at the POS and they're not going to want to pick up all that equipment and throw it out. So barcoding is going to be around for a long time.

Interviewer – I'd like to move onto discuss a little about RFID now. In Australia, has your organisation started to offer too many RFID applications?

Participant 1 – No, primarily because in Australia the EPC standard has only just recently been ratified and ticked off. RFID itself isn't a new idea, we've had RFID products previously, with active RFID tags and readers. But we've found because it is a not standard thing, like you've got the UPC standard and the EPC standard, because the RFID products we've had in the past have been non standard, you can't integrate them throughout the supply chain - So they don't really add value. It would be like if Coca-Cola used one barcode type and Gillette used a different barcode type, ti would get too hairy for the retailers, so we just need a standard thing across the SC.

Interviewer – So the importance of the EPC is paramount?

Participant 1 – Absolutely.

Interviewer – What are the typical applications of RFID in the SC?

Participant 1 – so the quick win for RFID. Dealing with the EPC is going to be a long term thing because the whole EPC network isn't just the traditional paradigm of, I have a barcode scanner, that's going to read a barcode, talk to a computer and pull it out of a database. That allows the user to update inventory stock and upload it to the database (UPC). With the EPC, it is looking at having all that as a remote key, so no matter where you are you will be able to read that data, push it back through the whole system of servants and various other bit of hardware, to plug into a global database, draw down that information from the database, and upload it again on the fly. So you could be out on the road in a courier truck going the temperature has gone above -3, this items a write off and already have it updated in the database.

Interviewer – What will be the most important factors with RFID?

Participant 1 – The immediate one is going to be pallet labelling and container labelling. So rather than having an RFID tag on every can of coke you buy, you will still have a barcode on every can, but you will have an RFID tag replacing the SSCN shipping notice on the pallet. So instead of putting a number of pallets together, shrink-wrapping them and putting a barcode shipping notice on that, then shipping your advanced shipping notice to the person that is going to be receiving it, so that when they get that shipping notice they can put that into their system, when it gets received they can tick it all off. What will happen is the pallets will be shrink-wrapped with an RFID tag attached, upload the data on that RFID tag through the database system, so at the other end they will be able to download that data negating the need to send an advanced shipping notice.

Real-time live information that can be updated at any point.

Interviewer – So non-line-of-sight capabilities come into play here?

Participant 1 – Yes, but there is a little bit of a misconception about non-line-of-sight. Non directional line-of-sight is probably the better way of saying it. With a barcode, you do have to have a laser pointing at the barcode, because of the nature of RFID and the radio spectrum, you do have to propagate the waves in a direction. So there is a directionality element, but you can still have obstructions and things in the way.

Interviewer – So this could lead to accuracy problems?

Participant 1 – Absolutely, for example, if you have a warehouse full of paper, getting it covered with a wireless LAN is a nightmare.

Interviewer – So this would also plague remote data capture for barcode scanners as well.

Participant 1 - Yes, absolutely. RDC works by having a barcode scanner with a wireless device on it, so it can talk back to a DB so you can do whatever you have to do. So if you've got a warehouse full of paper or metal or water or liquid etc. when you install that wireless LAN to begin with, you get a lot of interference and multi-pathing and all this weird radio frequency stuff, because of the nature of what is being stored. So communication becomes really hard.

When you're dealing with RFID you've got a lot less power in that system compared to a wireless LAN.

Interviewer – So what do you believe to be the three most inhibiting factors to RFID?

Participant 1 – The environment is going to be a big one, the cost is also going to be a big one because when you look at it throughout the SC, not only are you going to have to buy a tag for every item you decide to tag, be it a can or pallet, that is going to be anywhere from $0.50 - $3, at this point in time. As well as readers and the network infrastructure to get those readers to talk back to the DB. Plus there is the added over head of when you install those readers, it is not just a case of putting a reader in somewhere like a dock door, you have to completely spec the requirements of that reader out. Just the concept of scanning everything that goes through that door with an RFID reader, that means you don't want to scan anything that is in front of the door or on the other side of the door or a little bit to the left or right. Therefore, you have to really focus on what you want to be scanning.

Interviewer – So RFID readers can be oriented in a particular direction

Participant 1 – Yes, it is like a wireless LAN, so you can add antennas and direct the radio wave propagation in a certain way. By itself it would spread conically, but if need be you would be able to have areas where stock is not allowed to be stored.

So there are all these little considerations, scanning through paper, liquid.

Interviewer – So with Wal-Mart mandating RFID compliance, and numerous other companies following suit, do you see Australian organisations waiting to see what happens or taking a more proactive approach.

Participant 1 – RFID has a lot of mindshare at present, it is very much in industry papers and newspapers. There is a lot of hype and that is probably one of the biggest problems with it. People are looking for the next big thing, so there is a lot of hype, a lot of fear, uncertainty and doubt about what it is going to deliver, and more importantly, about what it is not going to deliver. So it is important to understand what you are not going to get out of it and what you are going to get out of it.

Interviewer – So is the market holding off on purchase barcode equipment as they are waiting to see what will happen with RFID?

Participant 1 – No not at all. People need something to solve a problem that they have now, and barcode is the technology that we have now. It is going to be around for 10, 15, 20+ years, especially when you are dealing with things such as consumer items going through point of sale. So small little mum and dad corner shops are not going to want to install an RFID system.

Interviewer – A number of manufacturers are worried that in complying with RFID mandates, they will have to outlay a lot of money and do see any return for themselves. Is this a big issue?

Participant 1 – Yes that is part of the problem and that is probably where Wal-Mart when a little bit too far, personal opinion, in trying to get RFID going. It has done huge things by mandating and saying, ok we want RFID because it's an emerging technology. The EPC is going to be the standard that we will work with. But again, forcing people to do something is always going to create some resentment and pushback.

Interviewer – Do you think that the benefits your current barcode solutions offer to manufacturers will be similar to what RFID will offer them?

Participant 1 – In the long term, yes. Just the very fact that with RFID you won't need to send out that advanced shipping notice anymore. You won't need to do anything more than program the RFID tag, stick it on, put it in the truck and send it on its marry way.

Interviewer – So at a high level the advantages of RFID are quite similar to that of barcodes, for manufacturers.

Participant 1 – If you go to a high level, an RFID tag is really just a complex barcode. It stores a digit or an alphanumeric string. Which is the linking key to a DB. Active RFID tags introduce a whole new level of complexity.

Interviewer – So will active tags play much of a role with SCM?

Participant 1 - Perhaps for high level tracking with pallets, but otherwise no. They also create a problem when you have more than one active tag, you have a lot of multi-pathing and interference as tags jump out and say look at me, I'm here, I'm here and they are going to start interfering with one another.

Interviewer – A lot of people say that line-of-sight will take errors out of RFID, as opposed to Barcodes, but the fact that you can't see what you are scanning at could create some doubt with manual RFID scanning?

Participant 1- Yes, there are ways of getting around it, but yes, it is a complexity. It is a similar problem to the dock door.

Interviewer – Environmental factors can cause problems with barcodes. What sort of accuracy rates do you achieve with barcode scanning?

Participant 1 – The biggest problem that we have found with barcoding is that distribution centres out west, can run for 24 hours a day. So you get the full morning sun shining on your pallets to be picked up and barcoding works by reflecting light. So if you have full sun shining on your barcode it really makes it hard to read that code. When environmental issues come in to play, RFID will be a godsend to read.

You will just have to load it onto the truck without having to scan it.

Interviewer – Thankyou for participating in this interview.

A2 – Interview Two

Participant's Organisation Positioning – Oil Refinery

Interviewer – What are the current applications of barcodes at the refinery?

Participant 2 – we have barcoding in two areas in the refinery.

> One is a very simple application, which is our laboratory information system. It monitors samples going out or coming in with barcodes. It ensures that each sample is given a unique ID number. This is done for all oils, petrol's and all other petroleum products. So we barcode them, we know what is coming in, we do all the different steps, and at the end the same barcode is scanned right through and at the same time we monitor samples going out. It is all simple entry which means that it is not a very complex application. The system is made up of a database, which can print out barcodes that adheres to a specific sample. Right through the whole process this barcode is scanned and operators enter different reading measurements at each different stage. So that is our most simple application. This system is maintained, run and managed by the IT department.
>
> Our other barcode application is to monitor tools, which uses a program called Intellitrack that is linked to an MS Access database. The system is a very useful and low cost solution. I use it in two areas. One is our central tool room (CTR) where we control and measure the tools in and out, and use the software to check tools on loan in and out. Say for example I have 300 trades people working in the refinery, a lot of tools we only stock about 10 or 20 pieces, as it is not possible to keep 200 or 300 pieces of each tool. Tools are managed on a share or loan basis, a first come first served basis. So when all those tools are loaned out and trades people want one of them, we can do a fast check to see when it was loaned, who it was loaned to and when it is due. If it is overdue then we can publish a report requesting it be returned.
>
> This system involves scanning the trade person's ID card and then the tool's barcode. When the tool is returned, it is scanned into the system logging it back to the tool warehouse, a simple process.
>
> In addition to this, we use this system to control our fire retardant garments, checking them in and out. When you are working inside the process unit at the refinery you are required to wear fire retardant clothing.
>
> This system is very useful for tool and consumable control when the refinery has a shutdown. In a shutdown, there are large number of tools being checked out, putting a strain on our tool resources. The system will let us know if someone tries to checkout more than one of any particular item, allowing us to query the person.

That is more or less the two biggest applications of barcoding in the refinery - Laboratory information system and the tool and clothing management systems.

Interviewer – What are the primary advantages of the tool and fire retardant garment barcode systems?

Participant 2 –

- It provides better overall management.
- Stops theft
- We know who has what – for example if someone has a hydraulic tool for undoing nuts, they are worth $9000 each and we only have two. So should there be an urgent job that requires the tool, I can lookup who has the tool and request it back.
- Provides a traceable record

Before the system was implemented we had no control over tool borrowing. So we were losing a large number of tools and could not track down where they were going. Tradespeople would borrow a tool or even a tape measure and not return it.

Interviewer – Does the system have to be audited?

Participant 2 – Yes, we do audits and chase up overdue tools. We publish a list of overdue tools every Friday to our major contractors. One of our major contractors currently has an overdue tool that is missing worth $37500. If they do not return the item I can send them a bill for the tool.

Interviewer – So what disadvantages such as the effect of the environment, are there?

Participant 2 – On each tool, we actually engrave the extension number. Every type of tool has a number, for example every ring spanner has the number 222142 and an extension number. So if there are 10 of these spanners the extension numbers would go from 1 – 10. This allows every individual item to be tracked as they actually carry a unique ID, meaning that once a tool has been checked out it cannot be swapped between trade's people.

A barcode is also attached to all tools, so should it become damaged the tools engraved ID number can still be seen, allowing the barcode to be easily replaced.

Interviewer – Is it very common for a barcode to become damaged?

Participant 2 – Yes they do, especially in a shutdown. A team leader will often come in after hours and print out replacements for all the barcodes.

Interviewer – So are there any other disadvantages with that system?

Participant 2 – The main one is replacing damaged barcodes. RFID may provide a an advantage of barcodes here. RFID tags are a lot stronger and can be more

permanently secured to the item. They can be easily scanned, and if RFID readers are extensively installed it could notify us where the tools are.

Interviewer – Just on barcodes, do the refinery have to conform to any standards?

Participant 2 – Internationally are a lot of standards, we just use what we call code 39. A lot of people in Australia just use serial 39 or 128 that is quite common, but you will find barcode scanners that do any standard.

Interviewer – Has RFID been considered for any applications at the refinery?

Participant 2 – Yes, it is part of our strategy that we will look into RFID because [parent company] in the U.S., which is our parent company is currently pushing RFID.

Interviewer – How would you be looking to use RFID in the refinery?

Participant 2 – Mainly on materials, tools or even PCs. For example if we implement an RFID system and collaborate with one of our major suppliers, they can put an RFID tag on all good coming in. This would mean that readers could automatically scan items coming in. Once items are loaded onto a trolley they can be taken through a reader and the employees tag can be scanned at the same time. This would manage all the receiving with our SAP system. This would mean that our vendor wouldn't have to send receipts, as soon as the goods are received we could pay them. The RFID system would also allow us to know exactly what stock we have on hand.

Interviewer – Have you considered using RFID to track tools?

Participant 2 – Yes we have, depending on which type of RFID tag we used, active or passive and our RFID infrastructure, it would allow us to track tools regardless of where they are in the refinery.

Interviewer – So the refinery is still evaluating the potential of RFID?

Participant 2 – Yes, it is part of the refinery's strategic plan. As it will take several years to roll out any RFID system, we are looking into it now to see where we can justify an application. In the long term, RFID will come to Australia, it will take another 4 years until it will be everywhere.

Many people are asking, if RFID will replace barcoding. The answer which quite a lot of people will tell you is no, RFID will not replace it. RFID is suitable for specific applications that cannot be matched by barcoding. Many small companies who cannot afford RFID initially will stay with barcoding as it is cheap, simple and stable and has well developed international standards. Also RFID does not have an international standard as yet, so it will take a few years to develop. In addition to this, the price of RFID tags still need to drop. The price has halved over the last year, however this trend needs to continue. When tags drop to around 1 or 2 cents, they will really put a lot of pressure on barcodes, but this is quite some time off.

Interviewer – What sort of accuracy is achieved with the tool management barcode system?

Participant 2 – Typically, there will be one error for every 100 scans. The system will notify the operator if the barcode scan does not match a tool, which allows me to enter the tool correctly and replace the barcode.

Interviewer – I have read that Star City Casino has placed RFID tags in every uniform to monitor their use and stop theft. Would your organisation consider using RFID to monitor your fire retardant garments?

Participant 2 – Barcodes on clothing are good, however RFID is much better. The barcodes on our fire retardant clothing wear out over time and cannot be scanned. When this happens our laundry company has to put a new barcode on. Unfortunately their system cannot print the same barcode twice so they have to attach a new barcode and notify us so that we can update it, which can be time consuming. RFID would be a lot more durable, as the tags are very durable.

Interviewer – Are your barcode systems used to help manage quality control?

Participant 2 – Yes, for tool management they are used for preventative maintenance and calibrations. Some of the specialised tools we use require recalibration every two months. The tool management system alerts the operator when they are checking out a tool that requires recalibration within a week. This means that the operator can tell the tradesperson that they can only have the tool for a limited amount of time before it needs to be recalibrated. If an item is already checked out, the system will notify the operator that the tool requires recalibration.

Interviewer – Thankyou for participating in this interview.