RADIO FREQUENCY IDENTIFICATION:

ADOPTION OF RFID

IN NEW ZEALAND SUPPLY CHAINS

By

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ABSTRACT

In the last decade, Radio Frequency Identification (RFID) technology has been widely used in industries for controlling and monitoring purposes but has limited application in supply chain management. Passive tags are used in commercial offices for access control, while a more active and powerful tag is deployed in highways for electronic road toll collections. Other non-contact, close range methods are popular in subways and other public transport systems.

The use of RFID in supply chain management is an emerging technological trend that has attracted a lot of attention in the U.S., Europe, and Asia. This is largely driven by the potential benefits that RFID technology is perceived to deliver in the supply chain, particularly, supply chain visibility. Major retailers and leading corporations around the globe are already testing and implementing RFID, and claiming to have achieved competitive advantages and return on their investments. It is, therefore, important to understand the adoption of RFID in New Zealand supply chains, so that appropriate actions can be taken to ensure that New Zealand companies are not lagging behind.

This research study explores and explains the adoption of RFID in supply chains using exploratory survey and case study. The research questions are:

1. What specific benefits can be achieved in organisations by using RFID?
2. What are the barriers to realising these benefits?
3. How and why do organisations adopt or not adopt RFID in supply chains?

Three factors were found to be important in the adoption of RFID in New Zealand supply chains. They are the compatibility of RFID with existing organisation's systems and values, the availability of supports to facilitate RFID adoption, and the readiness of the internal and external organisation's environment. It was also found that complexity of the technology and the relative advantage of using RFID were to a certain extent influencing users' perception of RFID compatibility. Dependency on trading partners was found to have some effects on RFID adoption.

A theoretical framework of RFID adoption in supply chains is proposed. This framework helps to bring out the important factors in the adoption of RFID in supply chains. While most IS research is focused on individual technology adoption or on intra-organisational technology adoption, this research is focused on technology adoption that involves or has impacts on trading partners, that is, at supply chain level. It provides a three-dimensional evaluation framework which includes technological, organisational, and environmental aspects of inter-organisational technology adoption.

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GLOSSARY

3G	Third Generation
AIDC	Automatic Identification and Data Capture
AS/RS	Automated Storing and Retrieving System
CFO	Chief Financial officers
CPFR	Collaborative Planning, Forecasting and Replenishment
CRM	Customer Resource Management
DOD	Department of Defence
EAN	European Article Numbering
EAS	Electronic Article Surveillance
EC	European Commission
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
EPC	Electronic Product Code
EPCIS	Electronic Product Code Information Systems
ERP	Enterprise Resource Planning
ETSI	European Telecommunications Standards Institute
FDA	Food and Drug Administration
FHSS	Frequency Hopping Spread Spectrum
FMCG	Fast Moving Consumer Goods
GLN	Global Location Number
GPS	Global Positioning Systems
GRAI	Global Returnable Asset Identifier
GSM	Global System for Mobile Communication
ISM	Industrial, Scientific, and Medical radio bands
ISO	International Organisation for Standardisation
JAN	Japanese Article Numbering
LBT	Listen Before Talk
MAF	Motivation/Ability Framework
MICR	Magnetic Ink Character Recognition
ONS	Object Naming Service
PML	Physical Markup Language
POS	Point of Sale
QR	Quick Response
RFID	Radio Frequency Identification
RFID/SC	RFID for Supply Chain Management
ROI	Return on Investment
RPV	Resources, Processes, Values theory
RTLS	Real-time Locating Systems
SGTIN	Serialised Global Trade Item Number
TAM	Technology Acceptance Model
TEU	Twenty-foot Equivalent Unit
TOE	Technology-Organisation-Environment

TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TTF	Task Technology Fit
UCC	Uniform Code Council
UHF	Ultra High Frequency
UPC	Universal Product Code
WAN	Wide Area Network
WMS	Warehouse Management Systems

CHAPTER 1 – INTRODUCTION

1.1 Overview

The instruction on the back of a frozen lasagne packet explains the heating methods before one can enjoy the hot delicious meal. It says 'Cook on HIGH for 6-8 minutes' in a microwave. Reading further down, one will notice a smaller print clarifying the microwave instruction is based on an 850W oven. How many times have you cooked a frozen meal incorrectly? The meal often has to return to the microwave until it is reasonably cooked. Professor Sarma (2005) and his students discovered a novel way to prepare tasty lasagne. They attached a radio frequency identification (RFID) tag to a food packet and placed the packet in a microwave oven installed with an RFID reader. When the microwave oven was started, the reader read the information stored in the tag, downloaded the heating instruction with the information, and started heating the food correctly. This is a remarkable technology of the twenty-first century.

Having successfully cooked the lasagne the RFID way, Professor Sarma and his team with some sponsorship, set up the Auto-ID Center to further develop the RFID concept. It was conceptualised as the electronic product code (EPC) standard used to identify a large number of objects. Wal-Mart took interest in the concept and decided that it would help with their supply chain visibility issues and mandated their suppliers to adopt the technology when supplying orders to Wal-Mart stores. Since then, other major retailers such as Target (Anonymous, 2004b), Best Buy (Wasserman, 2005) and Albertsons (Collins, 2004a) in the United States, and Metro (Roberti, 2007a) and Tesco (Anonymous, 2003b) in Europe have started implementing RFID with their suppliers. Additionally, leading third-party logistics

providers, such as DHL, UPS, FedEx, Maersk Logistics and APL Logistics are actively involved in designing RFID solutions for their customers (Wasserman, 2005).

However, the implementations have not been a smooth sail. At the initial rush to RFID implementation, companies were faced with reliability issues such as read rate accuracy (Smith, 2005), radio frequency interference (Alu, Sapia, Toscano, & Vegni, 2006), tag quality (Smith, 2005), standards interoperability (Vijayaraman & Osyk, 2006) and data collection (Angeles, 2005) to name a few. Besides the technical issues, there are costs and benefits (Sarma, 2001; Smith & Konsynski, 2003), and privacy issues (Jones, Clarke-Hill, Comfort, Hillier, & Shears, 2004; Sarma, 2005) that companies have faced. Other issues are supports in terms of management and expertise in facilitating the pre-investment evaluation and trial.

In New Zealand, there are unique logistics issues faced by New Zealand businesses. The long distance to New Zealand major markets poses challenges in the movement of goods, particularly, perishable goods. Most businesses in New Zealand are small to medium size, and thus, they have an issue of purchasing power or power in dealing with larger trading partners. Due to the relatively small economies of New Zealand, challenges arise around suppliers and customers showing preferential in partnerships. This has created the isolations of power and collaboration issues. In terms of technology adoption, there seems to have a lack of sophisticated information systems in New Zealand supply chains (Basnet, Childerhouse, Foulds, & Martin, 2006). It is therefore an opportunity for New Zealand businesses to explore the possibility of using RFID technology to mitigate these shortcomings.

1.2 Research Motivation

There are two motivations to doing this research. First, this research is motivated by the increasing popularity of RFID within the supply chain area. There has been much interest by companies around the world on the use of RFID to manage their supply chain operations. New Zealand is no exception to this phenomenon. Companies in New Zealand have been involved in RFID in a variety of ways. However, the adoption of RFID in New Zealand has been slow (Bell, 2004b). The results of surveys completed by iStart, a New Zealand information hub, in 2006, 2007 and 2008 show little or no change in the adoption status of RFID. 85 per cent of respondents have no intention to invest in RFID in New Zealand. The most prominent cases of adoption in New Zealand are Yakka Apparel in military equipping (Elmes, 2005), The Warehouse in retailing (Bell, 2005), Progressive Enterprise in meat processing (Anonymous, 2005), and EastPack in kiwifruit exporting (Friedlos, 2008b). This research attempts to further uncover the development of RFID adoption in New Zealand.

As the world explores RFID for the supply chain, industries and governments are getting together to form their own communities with the objective of advancing RFID development (Bacheldor, 2007; Swedberg, 2007a; Wessel, 2007b). This further accelerates the development of RFID into the various forms of logistics and supply chains. It is thus a motivation of this study to explore the benefits and barriers to the adoption of RFID in supply chains.

Second, the excitement about RFID benefits and the quickening pace of development have caused researchers around the world to study the use of RFID for supply chain management (RFID/SC). Many studies are focused on the technical aspects of radio frequency (Alu, et al.,

2006; Li, Visich, Khumawala, & Zhang, 2006; Porter, Billo, & Mickle, 2006). They are focused on readability, data accuracy and security of RFID systems. Others describe the impacts, benefits, and visions of RFID on business (Jones, Clarke-Hill, Hillier, & Comfort, 2005; Smith, 2005; Twist, 2005). There are, however, few empirical studies on RFID implementation (Martínez-Sala, Egea-López, García-Sánchez, & García-Haro, 2009; Tewary, Kosalge, & Motwani, 2009; Vijayaraman & Osyk, 2006). It is thus the intention of this research to add to the field of technology adoption at the organisational level by investigating the adoption of RFID in supply chains using a qualitative approach for a more in-depth inquiry.

While the RFID take-up in New Zealand is not as high as in the U.S., Europe, and Asia, this research first looked at the status of RFID adoption in New Zealand using survey and then explored the adoption process of organisations using case study.

As the subject is about RFID adoption, theories used in technology adoption are researched and scrutinised for relevant frameworks, models, and variables that are applicable to this study. Several individual technology adoption theories as well as organisational theories are reviewed in this study. Other theories are drawn from top information systems journals, supply chain journals, and from journals dealing with organisational behaviour. For example, the adoption of personal computing systems, Electronic Data Interchange (EDI), and supply chain software applications are some of the studies reviewed for this research.

1.3 Research Objective

The research objectives of this study are to find out the benefits and barriers of RFID technology, and ascertain how organisations make the decision to adopt or not adopt RFID technology in supply chains. Therefore, three research questions are proposed.

1. What specific benefits can be achieved in organisations by using RFID?
2. What are the barriers to realising these benefits?
3. How and why do organisations adopt or not adopt RFID in supply chains?

This chapter provides the overview of this research study. It describes all the chapters in this thesis and highlights key information in each chapter that readers should know. It also explains how the thesis is organised. The next section describes the organisation of the thesis. This is followed by the description and the highlights of the chapters.

1.4 How this Thesis is organised

There are a total of seven chapters including this one. Chapter 1 outlines the thesis. Chapter 2 consists of the literature reviews of three key components of this research: Information Systems (IS), Operations Management (OM) and RFID. Chapter 3 outlines the research methodologies and research design. Chapter 4 is about the survey on RFID in New Zealand. Chapter 5 is the introduction and analysis of the case study. Chapter 6 is the discussion of the results of the case study, and chapter 7 is the conclusion. The remainder of this chapter briefly describes each of the chapters and highlights the key subjects.

1.5 Chapters 1 and 2 – Introduction and Literature Review

Chapter 1 introduces the research with highlights on the motivations and research questions. It also provides an overview of the chapters. Chapter 2 is the literature review chapter. It is consisted of seven main sections: RFID, Supply Chain Management, RFID for Supply Chain, Technology Adoption Models, RFID Adoption in Supply Chain Studies, Problems, Issues, and Requirements, and Factors as Enablers of RFID/SC Adoption. The RFID section covers the history of RFID in general. The RFID section provides background information to what RFID was and how it was used in the early development days. As RFID is an automatic data capturing technology, the section also looks at the various Automatic Identification and Data Capture (AIDC) technologies. Barcode, a form of AIDC and in many ways similar to RFID, is described and compared to RFID. The section concludes with the applications of RFID in New Zealand.

The second section covers the topic of supply chain management with focus on the shift of power in supply chains. The contribution of this section is the finding of a three-tier effect of the RFID mandate on supply chains. The section concludes with an overview of supply chain management in New Zealand context.

The third section covers the applications of RFID in supply chains. The benefits of RFID in supply chains are highlighted and four key barriers of RFID in supply chains are discussed. It provides a clear understanding of the employment of RFID in supply chains. The section concludes with the status of RFID in New Zealand supply chains.

The fourth section covers the review of the relevant technology adoption and diffusion theories. A total of three individual technology adoption theories, Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), and Task-Technology Fit (TTF) models, and three organisational theories, Diffusion of Innovation (DOI), Motivational/Ability Framework (MAF), and Technology-Organisation-Environment (TOE) framework, were reviewed. The section also compares the models and suggests that a supply chain view is required in the study of technology adoption in supply chains.

The fifth section covers the scholarly studies in RFID in supply chains adoption. As this field is fairly new, the literature review covers publications from 2004 to 2009 and performs a gap analysis. This section provides the justification to the conduct of this research.

The sixth section covers the problems found in the adoption of RFID in supply chains. Issues related to the problems are identified and the potential requirements to solving the problems are proposed. The requirements are formed as the scope of the research.

The last section of chapter 2 highlights ten factors as the enablers of RFID in supply chains adoption. These factors are derived from the requirements identified in the preceding section and from the technology adoption literature. The factors are used to define the scope for the research but not limited to.

1.6 Chapter 3 – Research Methodology

Chapter 3 is an important part of this thesis. It outlines and discusses the research problems and forms the research questions. Much of the chapter is devoted to the research methodologies and research methods in the IS field. The research approach of this research is stated. Research design is also outlined. A survey is conducted to find out the status of RFID adoption in New Zealand and case studies are conducted on the adoption of RFID in New Zealand supply chains.

1.7 Chapter 4 – Exploratory Survey

Chapter 4 discusses the conduct and results of the survey. Key benefits and barriers to the adoption of RFID in New Zealand are revealed in the survey. The contribution of this survey to this research as a whole is the generation of more inquiries into the specific areas where answers to adoption of RFID may lie. The questions raised in the chapter are listed here.

1. Are the lack of agreement on standards, integration, and expertise the true technology barriers to RFID adoption?
2. How important is investment cost to an organisation when evaluating RFID in supply chains?
3. What are the motivational and ability factors that drive RFID in supply chains adoption?
4. How does an organisation proceed with the assessment of RFID in supply chains that leads to the decision to adopt or not to adopt RFID?

These questions help to form a conceptual framework of the organisational technology adoption process in three dimensions: technological, organisational, and environmental. This leads to the next stage of the research – the case-based study.

1.8 Chapters 5 to 6 – Case Study Analysis and Discussion

Chapters 5 and 6 contain the analyses and findings of the case studies. Chapter 5 discusses the case companies' profiles by grouping the companies into the three supply chain groups: suppliers, distributors, and retailers. Individual companies are described first and then the findings of the case studies are presented. In each group, the companies are compared and analysed. A cross-group comparison is also conducted. The similarities and differences within the groups and the cross groups are also highlighted. Each section concludes with a summary of the main highlights of the sections. The highlights are tabulated in summary tables for comparison.

Chapter 6 discusses the themes and findings of the case studies. A total of twelve themes and their findings are discussed. The discussion is contextual based as well as the perceptions as reported by the participants. The key component in this chapter is the proposal of a conceptual framework for the adoption of RFID/SC.

1.9 Chapter 7 – Conclusions

Chapter 7 is the conclusions chapter of the research. It is considered an important chapter as it groups all the research components in one chapter. The chapter starts by revisiting the overview of the research objectives and research questions. A key component in the chapter is

to link the research outcome to the research questions. Comparison with other research studies is another key component of the chapter. Managerial implication, research limitations and future research are highlighted towards the end.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

This research covers three main subjects: Information Systems (IS), Operations Managements (OM), and RFID. Figure 2-1 shows the overlapping of these three subjects in the context of New Zealand.

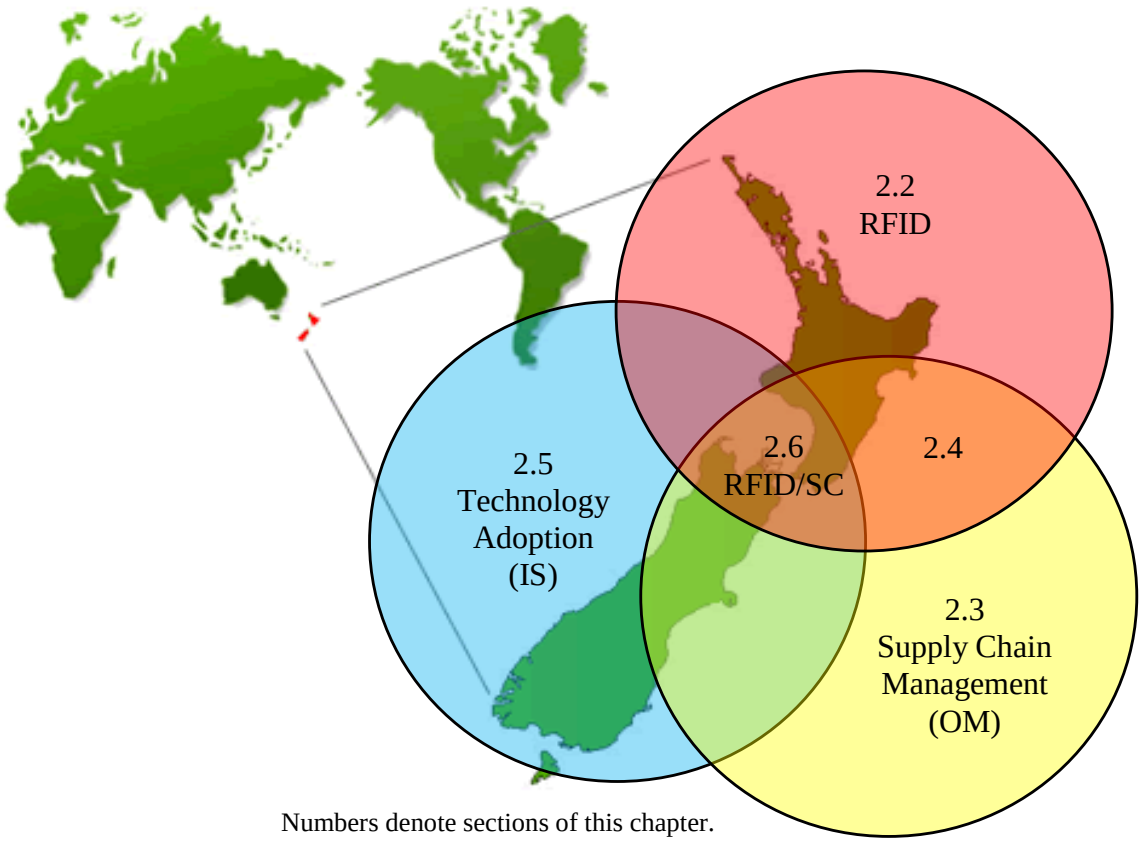


Figure 2-1: About the Research Fields

The title of the thesis suggests that technology adoption in New Zealand supply chains is the main topic of discussion. RFID technology is selected as the technology of investigation motivated by the recent hype in the use of RFID in supply chain and its potential benefits to

New Zealand economy. The advancement in e-commerce and digital technology is a fact and a trend that cannot be ignored by businesses. IS is part of all businesses and so is OM; every businesses has a supply chain of some sort. Thus the study of IS in the field of OM contributes to both fields in the followings: (1) the research adds to the knowledge of technology adoption in the IS field, and (2) the research introduces IS theories to the field of OM.

In New Zealand supply chains, there is a lack of sophisticated IS (Basnet, Childerhouse, Foulds, & Martin, 2006). The study will also contribute to the New Zealand supply chains by exploring how organisations can adopt RFID, a sophisticated IS, in their supply chains. In the field of RFID, most of the research is focused in the technical aspects of RFID. This research, however, focuses on the adoption of the RFID in supply chains. This has influence not only in New Zealand but in other parts of the world as globalisation extends an organisation's supply chains beyond domestic markets.

This chapter reviews the literature of these three subjects and is arranged as follows. The first section looks at the development of RFID and some technical aspects of RFID. It provides a summary of the use of RFID in New Zealand. The second section looks at the operations management field. It provides an overview of supply chain management in New Zealand. The third section looks at the use of RFID for supply chains. The benefits and barriers to the adoption of RFID in supply chains are discussed and a summary of RFID in New Zealand supply chains is provided. The fourth section looks at the IS field of technology adoption. Various adoption models are discussed and compared. The fifth section looks at previous studies in RFID adoption in supply chains. The sixth section discusses the problems and issues found in RFID in supply chains and identifies the requirements to resolving the issues.

The last section extends the requirements into enablers of RFID/SC adoption based on the technology adoption literature.

2.2 Radio Frequency Identification

RFID is an AIDC technology. Its application can be found in most industries, offices and even homes. RFID is fundamentally a radio technology and its history can be traced back to the 1930s (Bhuptani & Moradpour, 2005). The underlying principle of RFID is the transmitting and receiving of data in a form of electromagnetic energy. The primary components are tags and readers. Together these components form a coupling relationship where communication becomes possible. This chapter revisits the history of RFID development and looks at other forms of AIDC. This helps to form an epistemology of what RFID is and its origin, so that the various aspects of RFID characteristics can be related to when planning on an RFID project. The emergence of RFID has raised the question of barcodes' continued existence in the supply chain (Allen, 1991; Atkinson, 2004). It is therefore essential to know the characteristics of RFID and barcodes, and examine their future existence, particularly in the supply chain.

2.2.1 The History of Radio Frequency Identification

Electromagnetism was developed in the 1800s. Michael Faraday discovered that light and radio waves are part of electromagnetic energy and James Clerk Maxwell demonstrated that electric and magnetic energy travel at the speed of light in transverse waves (Landt, 2001). The discovery led to consequential experiments. In 1896, Guglielmo Marconi successfully transmitted radio waves across the Atlantic (Landt, 2001). Marconi's demonstration was followed by more innovations. In 1922, radar was developed. The transponder (or tag) and

interrogator (or reader) were then bulky and heavy. Radar was extensively used by the Allies during World War II to identify friendly military aircraft. Radar was further developed into a commercial air traffic control system in the late 1950s following the invention of integrated circuits (IC), which greatly reduced the size of RFID components. The 1960s marked the start of RFID development as scientists and commercial units/businesses started to show interest in the technology. The first concept of RFID for commercial use was probably thought of by Mario Cardullo in 1969 when he worked with an IBM engineer on a car tracking system using barcodes for the railroad industry (Shepard, 2005). Most RFID applications were developed in the 1970s. The use of RFID for electronic article surveillance (EAS) began in the early 1970s (Bhuptani & Moradpour, 2005). EAS is a simple anti-theft measure for use in retail stores. It is the first and most widely used RFID application commercially (Landt, 2001). Further interest in the adoption of RFID extended to areas such as vehicle tracking, access control, animal tagging, and factory automation. Examples are the use of RFID cards for access control to premises by Westinghouse (Mullen & Moore, 2005), and the experiment on the use of RFID in electronic toll collection systems by the New York Port Authority (Shepard, 2005). Further development improved the reading speed and enabled a longer read range. Advanced RFID systems were utilised to identify railroad cars and track animals in the 1980s, and for electronic toll collection in the 1990s (Bhuptani & Moradpour, 2005).

RFID applications became widespread in the 1990s. The success of electronic toll collection kicked off large scale deployments throughout the United States, Europe and Asia (Landt, 2001). There are two basic systems employed in road toll collection. One uses a contactless card or proximity card and the other uses a transponder fitted into the vehicle. The latter does not require the vehicle to halt at a barrier unlike the proximity card model where the driver has to stop and hold the proximity card close to the reader at the barrier or toll plaza.

Standards for contactless smart cards were developed between 1992 and 1995. Contactless smart cards are now widely used in retail electronic payment, access control, transport fare payment, and airlines ticketing.

It was not until late 1999 that RFID made its way into supply chains. Sanjay Sarma, a professor at MIT, started a project called the Distributed Intelligent Systems Center to work on ubiquitous object identification (Sarma, 2005). The centre developed the EPC, Object Naming Service (ONS), Physical Markup Language (PML), and the Savant system. Together these components form the fundamental mechanism in the RFID system known as the EPC network.

Sarma and his team developed a microwave prototype installed with an RFID reader. The reader read the tag information on a packet of food, retrieved the cooking instructions from a server using the tag identity or EPC, and started cooking with the downloaded instructions. Having successfully demonstrated the EPC concept using the microwave prototype, Sarma and his team were eager to secure commercial support as well as sponsorships to further develop the technology. After some convincing selling, they finally launched the Auto-ID Center with sponsorship from Gillette and Procter & Gamble on September 30, 1999 (Sarma, 2005). The Center continued its excellent research work, and by 2003 there were six laboratories and more than a hundred sponsors. The increasing demand and interest triggered the Auto-ID Center to spin-out and hence EPCglobal was formed. EPCglobal is a not-for-profit organisation jointly administered by Uniform Code Council (UCC) and European

Article Numbering (EAN) International, or GS1[1]. Under the GS1 umbrella, EPCglobal now reaches the entire globe with 104 member organisations (Smucker, 2006).

A turning point for the widespread use of RFID in supply chains came when Wal-Mart joined the Auto-ID Center in 2001 (Sarma, 2005). A major field trial was conducted which involved forty companies across eight states and ten cities in the United States. The trial was not only successful, it demonstrated the practicality of RFID/SC and its economic benefits. This prompted Gillette to order 500 million tags in late 2002 and Wal-Mart to announce their mandates for its suppliers in 2003. Both events proved to be the catalysts of RFID/SC adoption. Figure 2-2 shows the development of RFID described above in a time chart.

Other recent RFID applications are location sensing or Real-Time Locating Systems (RTLS), content management, electronic pedigree (e-pedigree), and in sports for time tracking. The use of RFID for location sensing applications has some successful implementation such as the WhereNet RTLS infrastructure used to track shipping containers at APL terminals (Violino, 2006). Other location sensing innovation using radios includes LANDMARC (Ni, Liu, Lau, & Patil, 2004), RADAR (Bahl & Padmanabhan, 2000), and SpotON (Hightower, Vakili, Borriello, & Want, 2001). The use of RFID for content management includes authenticating and monitoring the content of a desired inventory. Examples of such applications are the e-pedigree used in the healthcare industry (Swedberg, 2008b) and tanker monitoring systems used by petroleum companies to ensure the correct type of oil is delivered (Swedberg, 2008a).

[1] Uniform Code Council and EAN International merged to form GS1.

The use of RFID in the sports arena has several applications such as ticketing and recording the lap time of the NASCAR races (Edwards, 2008b).

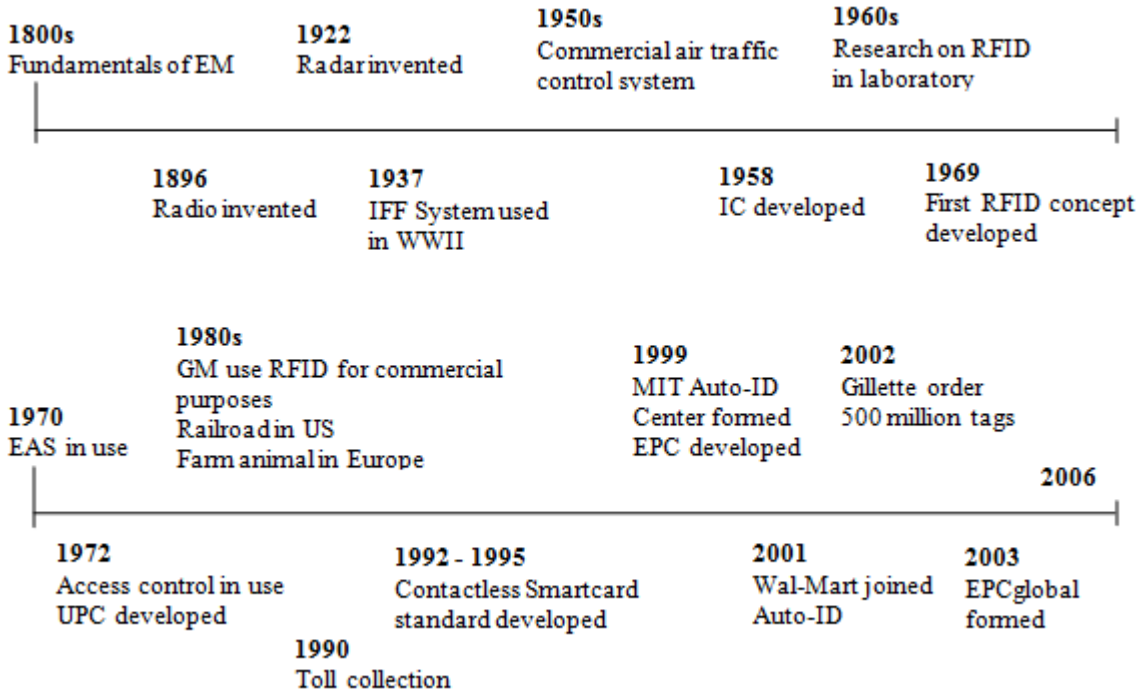


Figure 2-2: The History of RFID

2.2.2 Automatic Identification and Data Capture

This section describes the various concepts of Automatic Identification and Data Capture (AIDC) and traces the historical context of the related technologies in an attempt to draw comparisons to RFID and put in perspective the development of RFID technology. The objective is to outline the path of RFID innovation.

Finkenzeller (2003) highlights five types of AIDC systems; (1) Barcode, (2) Optical Character Recognition, (3) Biometric, (4) Smart Card, and (5) RFID. Figure 2-3 illustrates his AIDC

diagram. Magnetic – Magnetic Stripe and Magnetic Ink Character Recognition (Mullen & Moore, 2005) – has been added to the diagram to illustrate AIDC more fully.

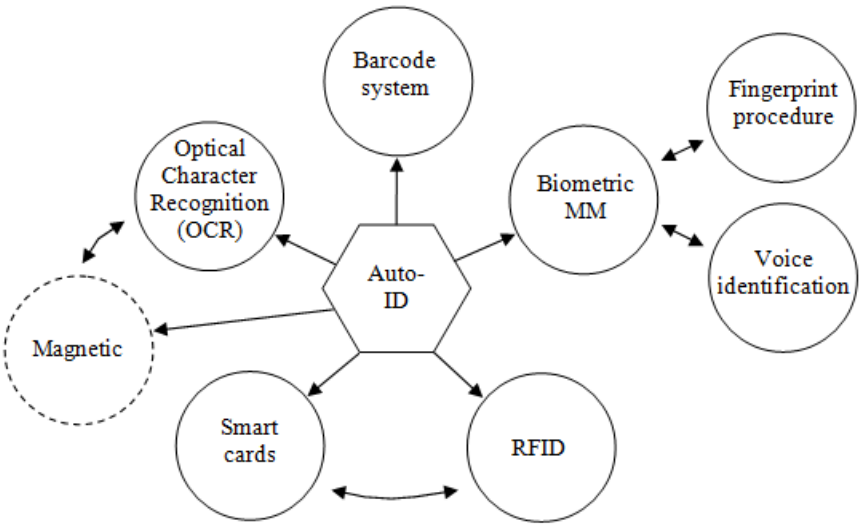


Figure 2-3: Overview of Automatic Identification and Data Capture (Adapted from Finkenzeller 2003)

The Barcode, Magnetic Stripe, and RFID technologies emerged between the 1930s and the 1940s. Barcode was first patented in 1949 to Norman Woodland and Bernard Silver (Shepard, 2005). Woodland used ancient movie soundtrack encoding schemes and the dot and dash patterns in Morse code to create the first barcode. He extended the dots and dashes vertically to a form linear pattern of thick and thin lines. He realised that the linear pattern had to be scanned from a particular direction. Woodland later replaced the linear pattern with a circular centric pattern resembling a bull's-eye. This design could be read generally from any direction. However, the machine he designed to read the barcode was huge and as such was not suitable for grocery checkout as it was originally intended. Nevertheless, it did find its way to tracking rail cars on the United States national railroad system in the late 1960s, albeit

with modifications to the barcode pattern. Meanwhile, barcodes continued to evolve around the grocery industry in the United States. The bull's-eye system was eventually replaced by the Universal Product Code (UPC) due to the difficulty of printing concentric circles on products. Linear barcode was adopted as it was easily printed and, with advanced scanners using laser technology, the linear barcode can be read from different angles. UPC was adopted on April 3, 1973 (Shepard, 2005), and was first scanned in commercial transactions in 1974 (Jilovec, 2004). As its popularity increased, international bodies started to ratify their own standards. EAN International and Japanese Article Numbering (JAN) are the other widely adopted systems. Barcodes thus became globally adopted in manufacturing, production, and distribution. There are now advanced barcodes with more data storage capacity such as the two-dimensional barcodes. Barcode, as referred to in this chapter, is the one-dimensional, linear barcode widely used in retail, manufacturing, and supply chain.

Magnetic Stripe is another AIDC in wide use particularly in the banking industry. Its standard was established in 1970 (Anonymous, 2007a). It is commonly used on credit and debit cards, and access control cards. The magnetic stripe when run past a reader produces an electromagnetic signal recordable by the reader. Another version of magnetic AIDC is the Magnetic Ink Character Recognition (MICR). MICR is also widely used in the banking industry for bank cheque authentication and both technologies were adopted by the American Banking Association (Mullen & Moore, 2005).

Optical Character Recognition (OCR) was introduced in the 1960s, almost twenty years after barcode's emergence. Like the MICR, special characters that are legible to both humans and machines are used to present a series of unique codes. OCR is also used in the banking industry and in the production, service and administrative fields (Finkenzeller, 2003).

More recently, biometric and smart cards have attracted interest. There are two main forms of biometric identification, one is voice recognition and the other is fingerprinting. A highly sophisticated system converts voice into digital signals to process the authentication of a subject. Voice identification is now being implemented in supply chain management to aid in picking orders (Allen, 1991; Kondratova, 2003). Fingerprinting recognises the unique finger patterns of individuals. As such, its application is commonplace around security and access control. A common application of fingerprinting is the employee time tracking system.

Smart cards first gained publicity as a pre-paid telephone card application launched in 1984 and, by 1995, 600 million smart cards were issued (Finkenzeller, 2003). Smart card is a secured data storage device widely used in Global System for Mobile communications (GSM) devices and as cash cards for micro-payments. It has a galvanised input/output connection with processing capability. An external power source is required to operate the smart card and the card needs to be placed in contact with a reader in order to allow for data transfer. Wear and tear to the smart card processor is inevitable with frequent usage and contact. Another version of the smart card, known as the contactless smart card, uses radio frequency (RF) technology where data can be transferred without the need to slot the card into a reader, thus no contact with the reader is necessary. The International Organisation for Standardisation (ISO) standard for contactless smart card was developed between 1992 and 1995 (Finkenzeller, 2003). A contactless smart card works in close proximity to a reader. It is thus suitable for applications where masses flow, such as, a high traffic channel. Contactless smart cards are for that reason widely used in public transport ticketing, allowing a quicker, smoother commuter flow through train station barriers or bus doors (Finkenzeller, 2003).

The preceding section shows that AIDC has evolved into a well-received technology for use in electronic payment, access control, production control, and distribution management. Barcodes and RFID are the two AIDC technologies utilised in supply chains where products are being identified at different stages from manufacturers to retailers, though RFID is relatively new in this domain. The rest of the AIDC technologies are primarily used in facility security, banking, and public transportation domains. Figure 2-4 shows the development of AIDC in a time chart. The rest of this chapter describes RFID in greater detail.

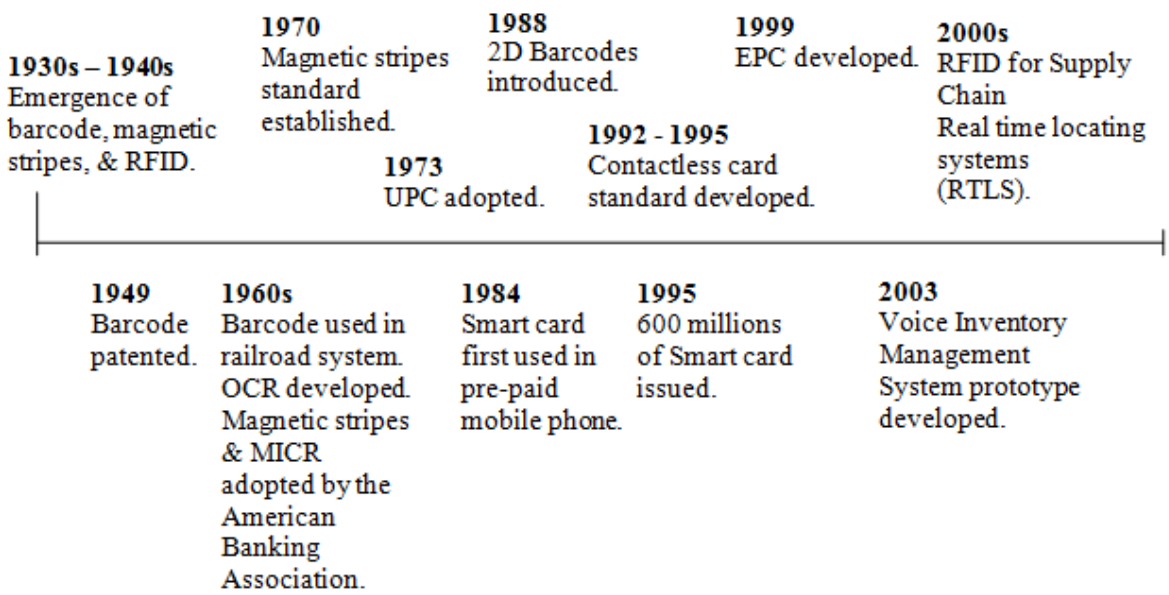


Figure 2-4: The Development of AIDC

2.2.3 About RFID System and EPC Concept

An RFID system is made up of two main hardware components: tags and readers (Grasso, 2004). The tags or transponders consist of a memory chip and have a built-in antenna. The memory, depending on its size, can store up to 64K of data. The antenna receives and

transmits data using radio waves. There are three basic forms of tags: passive, active, and hybrid or semi-passive. A passive tag does not have an internal power source to process nor transmit signals. An active tag has an integrated battery as the power source. An active tag can broadcast signals and transmit at a longer range than a passive tag. In contrast, a passive tag is only operational when it receives RF signals from an authenticated source or reader. The tag uses the RF as a source of power to transmit data back to a reader, a process called inductive coupling (Weinstein, 2005). A semi-passive tag has an on-board power source and yet behaves like a passive tag. It has a switch that turns on the internal power source when it receives RF signals from a reader. A semi-passive tag overcomes the short range limitation of a passive tag and the complexity of an active tag response method (Jones, et al., 2006).

Tags can be read only, write once and read many times, or read and write many times. There are six classes of tags: Class 0 to Class 5. A Class 0 tag is a factory-programmed read-only passive tag. Once programmed, the data in the tag cannot be altered. A Class 1 tag is similar to a Class 0 tag except that it can be programmed by the user. It contains minimum features to keep the cost low. A Class 2 tag is a read-write passive tag with a longer communication range than a Class 1 tag. It has extended memory and authenticated access control features not available in Class 1 tags. A Class 3 tag is a semi-passive read-write tag. It has an on-board power source and thus has a longer communication range and higher transmission reliability than Class 2 tags. A Class 4 tag is an active ad-hoc read-write tag with the functionalities of a Class 3 tag. It is capable of communicating with other Class 4 tags within range of its ad-hoc network. A Class 5 tag is an autonomous active read-write reader tag. It has the features of a Class 4 tag and is capable of communicating with all classes within its subsets. Each successive class “is a superset of the functionality contained within, the previous class, resulting in a layered functional classification structure” (Engels & Sarma, 2005, p. 3). Figure

2-5 shows the layered classification structure of tags. Class 0 is not shown in the figure as it could be classified as Class 1 due to their similar features. Class 1 is established as the foundation of the RFID class structure (Engels & Sarma, 2005).

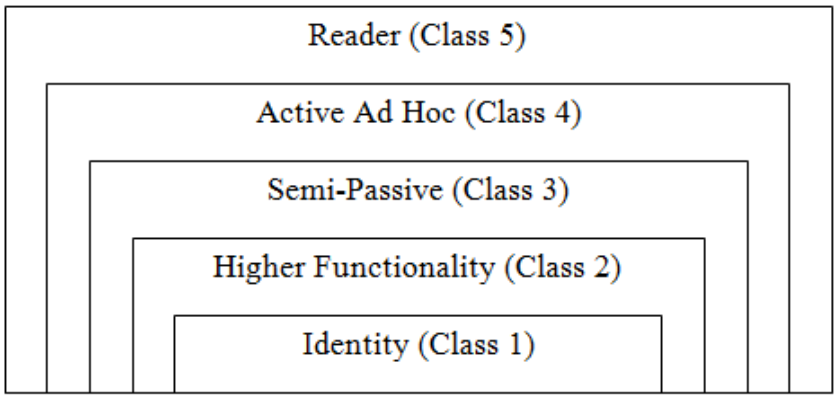


Figure 2-5: Auto-ID Center RFID Class Structure – Layered Hierarchy (Engels and Sarma 2005)

The use of a tag is controlled by the radio frequency spectrum. RFID utilises the Industrial, Scientific, and Medical (ISM) band available worldwide. There are four categories of spectra available for commercial use: 125 to 134 KHz in the low frequency category, 13.56 MHz in the high frequency category, 433 MHz and 868 to 928 MHz in the Ultra High Frequency (UHF) category, and 2.45 GHz in the microwave category (Walker, 2003). There may be some variations in the classification of spectra due to the different regulations on the use of ISM band in different parts of the world.

The 13.56 MHz spectrum is commonly used for RFID applications such as proximity access cards to premises, and smart cards. The 433 MHz spectrum is commonly reserved for supply chain use in most countries making it a suitable candidate for global supply chains. It was also

considered the industry standard for supply chains (Li, et al., 2006). The China State Radio Regulation Committee on 9th November 2006 approved the use of 433 MHz for RFID devices compatible with the ISO standard. This seems to solidify the 433 MHz spectrum as an international standard (Swedberg, 2006a). New Zealand has also assigned the 433 MHz spectrum for RFID and other short range devices. Unfortunately, frequencies in this spectrum do not work reliably under supply chain conditions due to the short wavelength of about one metre (Anonymous, 2004a). Thus a passive tag at 433 MHz might not adequately achieve the reading accuracy. The United States Department of Defence (DOD) has tested the interference of 433 MHz active RFID systems and maintained there is no interference between the RFID systems and radar equipment that they are aware of. However, the DOD is taking precaution not to deploy the RFID systems within forty kilometres of any military radar system (Collins, 2005).

EPCglobal on the one hand has ratified various standards for RFID operations. It has ratified the Generation 1 tag in 13.56 MHz, 860 to 930 MHz, and 900 MHz. The latter is a factory-programmed tag or Class 0 while the others are writeable or Class 1. A notable improved standard of EPCglobal is the Class 1 Generation 2 UHF tag (Wessel, 2007c). This standard allows interoperability across the 860 to 960 MHz spectrum making this standard more scalable and raising its tolerance to interference in a dense RF environment. The United States has adopted the 915 MHz frequency as the national standard for passive RFID systems (Porter, et al., 2006) which is within the EPCglobal defined range for UHF tags. The Australian Communications and Media Authority has issued a license to GS1 for the use of 920 to 926 MHz in Australia. The New Zealand Government, besides assigning the 864 to 868 MHz spectrum for RFID, has plans to freeze any further issuance of licenses in the band of 915 to 921 MHz to cater for future RFID uses (Anonymous, 2007c). The New Zealand

Government is adopting generic frequency standards across the ISM spectrum as a strategy for keeping the use of RFID devices and licensing open. The Government is actively discussing and harmonising the frequency arrangements with key trading partners such as Australia, Europe, and the United States. Such arrangements will make RF equipment easily available without incurring additional costs for modifying the equipment according to local standards. The European Commission on the other hand has planned to adopt the ultra-wide band frequency range of 3.4 to 4.8 GHz and 6 to 8.5 GHz among the European countries (Swedberg, 2007b). As of September 2007, there are a total of 54 countries with regulations in place for the use of RFID within the 860 to 960 MHz spectrum (Barthel, 2007). They represent about 92% of the world gross national income. Table 2-1 shows the allocated frequencies for RFID use in the 860 MHz and above UHF spectrum by countries.

The other component of an RFID system is the reader. A reader sends and receives RF signals. It may be portable or fixed in a position and is linked to a computer. In a proprietary system, readers usually read only proprietary tags. The readers and tags must be programmed within the same range of a spectrum to communicate. Thus, one of the biggest challenges is harmonising the frequency for RFID use in the UHF spectrum, particularly, in Europe where the available UHF spectrum is limited (Wasserman, 2007). For example, France, Italy, Spain, and Turkey were using the UHF spectrum for military equipment before the ratification of RFID use in the UHF spectrum (Barthel, 2006). The UHF spectra shown in Table 2-1 are the approved frequency slots for RFID use in the respective countries. This means that an RFID reader has to be tuned to the approved frequency slots for operation in that country. Therefore, the EPC Class 1 Generation 2 tags can roam internationally among these countries thus allowing a worldwide supply chain visibility in these countries.

Country	Frequency (MHz)	Technique	Regulator Website
Australia	920 to 926	NA	www.acma.govt.au
Brazil	902 to 907.5	FHSS	www.anatel.gov.br
China	840.5 to 844.5; 920.5 to 924.5	FHSS	www.mii.gov.cn
Finland	865.6 to 867.6	LBT	www.ficora.fi
France	865.6 to 867.6	LBT	www.arcep.fr
Germany	865.6 to 867.6	LBT	www.bundesnetzagentur.de
Hong Kong	865 to 868; 920 to 925	NA	NA
India	865 to 867	NA	www.trai.gov.in
Italy	865.6 to 867.6	LBT	www.agcom.it
Japan	952 to 954	LBT	www.soumu.go.jp
Korea, Rep.	908.5 to 910; 910 to 914	LBT; FHSS	www.kcc.go.kr
Malaysia	866 to 869	NA	www.cmc.gov.my
New Zealand	864 to 868	NA	www.med.govt.nz
Singapore	866 to 869; 920 to 925	NA	www.ida.gov.sg
South Africa	865.5 to 867.6; 917 to 921	LBT; FHSS	www.icasa.org.za
Spain	865.6 to 867.6	LBT	www.mityc.es
Sweden	865.6 to 867.6	LBT	www.pts.se
Switzerland	865.6 to 867.6	LBT	www.bakom.ch
Taiwan	922 to 928	FHSS	NA
Thailand	920 to 925	FHSS	www.ntc.or.th
Turkey	865.6 to 867.6	LBT	www.tk.gov.tr
United Kingdom	865.6 to 867.6	LBT	www.ofcom.org.uk
United States	902 to 928	FHSS	www.fcc.gov
Vietnam	866 to 869	NA	www.mpt.gov.vn

(FHSS – Frequency Hopping Spread Spectrum, LBT – Listen Before Talk, NA – Not Available).

Table 2-1: Frequency Allocation for RFID in the UHF Spectrum (Barthel 2007)

A reader broadcasts its signal within a specific spectrum depending on its power and frequency. The distance a tag and a reader can transmit is relative to the size of the antenna. In a same-frequency band, the larger the antenna, the longer the transmission range is. The orientation or shape of the antenna is equally important in its role of picking up electromagnetic signals, particularly when the tag is used on a material that attenuates the electromagnetic signals. Thus the "surface area and the shape of the tag antenna have to be optimised for not only backscattering the modulated electromagnetic wave but also harvesting energy for the microchip to function" (Ukkonen, Schaffrath, Kataja, Sydanheimo, &

Kivikoski, 2006, p. 111). There are now many shapes and sizes of antennas designed for use on different materials and environments.

There are also various transmission methods. The frequency hopping spread spectrum (FHSS) method switches channels in a sequence for a more reliable transmission. The FHSS method allows the efficient use of the bandwidth. The other method, used mostly in Europe, is the Listen Before Talk (LBT) method. In the LBT, a reader has to listen for other transmitters using the same channel before communicating with the tags through an unused channel (Eeden, 2004). This method is derived due to the restriction on the amount of energy emission in Europe set by the European Telecommunications Standards Institute (ETSI). A LBT reader is allowed to transmit signals for a period of four seconds and then stop the transmission for at least 0.1 second (Anonymous, 2007b; Roberti, 2004a). The disadvantage of the LBT method is the slower data transfer rate, which is about thirty per cent of the FHSS data rate (Roberti, 2004a).

To identify objects along a supply chain, the objects are tagged with EPC RFID tags. The EPC can uniquely identify the objects according to the encoding schemes such as the Serialised Global Trade Item Number (SGTIN), Global Location Number (GLN), and Global Returnable Asset Identifier (GRAI) (EPCglobal, 2005a). When the objects move into a reader's range, the tags respond by sending back the identifiers to the reader. The reader picks up the signals and transmits the information to a host computer (Li, et al., 2006). In the EPCglobal network architecture, a middleware is used to manage the real-time read events, filter duplicated data or noise, and sort the information. The EPCglobal network uses Internet technology as a way to access more information related to the EPC (EPCglobal, 2004). The ONS is used as a discovery method to access the correct EPC information. At business level,

managers can access and share meaningful information with their trading partners using the EPC information services (EPCIS).

EPCglobal is a joint venture by EAN and UCC (Frederic Thiesse & Michahelles, 2006) and now operates under the administration of GS1. GS1 is a global establishment with the objective of designing and implementing global standards and solutions, including barcode technology, in the supply chain.

> "GS1's goal is to simplify global commerce by connecting the flow of information with the flow of goods. Global commerce is multifaceted and the complexities innumerable; however, GS1 has focused its mission at the core of the challenge. GS1 will lead the design and implementation of global standards to improve the supply and demand chain" (Source: GS1's Vision & Mission statements, retrieved from http://www.gs1.org).

GS1 operates behalf of subscriber organisations and the development of standards is largely driven by its members. Under GS1's purview, besides EPCglobal, are barcodes, EDI, and global data synchronisation networks. GS1 manages and allocates a range of unique numbers to member organisations. EPCglobal accredited tags and readers ensure interoperability, which is critical in global supply chain management. Members can achieve supply chain visibility and efficiency with the standards and registered members can access the flow of information through the EPCglobal network.

The role of GS1 is crucial to the successful use of RFID in the supply chain. Besides imparting standards, GS1 also governs the use of EPC information by introducing guidelines for consumer product, patient safety, and intellectual property rights to name a few. By taking the lead in steering the development of RFID, GS1 not only accelerates the development, it

also motivates its members and potential members by harnessing and tackling foreseeable challenges, particularly those daunting global issues. GS1 brings together industry-driven standards that enable interoperability and diffuses[2] the technology to its member organisations by providing training and support.

2.2.4 Barcodes and RFID: Avoidance of Media Break

RFID is generally thought of as a replacement for barcodes (Atkinson, 2004; Lazar & Moss, 2005; Sheffi, 2004). Barcodes have been around since 1949 when they were first patented. It took almost thirty to forty years for barcodes to gain wide adoption. This is evident in the late 1980s to early 1990s when there were numerous articles on the application and implementation of barcodes; Walter (1988), Carter (1991), Lacharite (1991), Ekman (1992), and Burkett (1993) provide examples of barcode applications in various industries, to name a few. By the 2000s, the barcode is already an established technology. This is also evident in articles claiming barcode is still "alive" amidst the emergence of RFID (Katz, 2006) and proclaiming success stories of barcode implementations (Heinen, Coyle, & Hamilton, 2003; May, 2003); RFID was initially thought to be replacing barcode. The announcement by the Food and Drug Administration (FDA) in the United States about the use of barcodes for the labelling of medications further strengthens the barcode's position in the industry (Heinen, et al., 2003). A recent survey by Venture Development Corporation shows that the demand for barcode scanners is strong (Mason, 2005). Therefore the general preconception of RFID replacing barcode needs to be refined. It is important to understand the difference between

[2] Technology diffusion is when the application of the technology is broaden (Frankel, 1990).

RFID and barcodes in order to successfully implement an RFID system especially in a barcode dominant environment.

System parameters	Barcode	RFID
Typical data quantity (bytes)	1-100	16-64k
Content	Specific (SKU level)	Dynamic
Machine readability	Good	Good
Readability of people	Limited	Impossible
Line of sight requirement	Yes	No
Influence of dirt	Very high	No influence
Influence of covering	Total failure	No influence
Influence of direction and position	Low	No influence
Influence of metal and liquid	Very low	High
Degradation/wear	Limited	No influence
Reading speed	Low (one label at a time)	Very fast (multiple tag)
Reading distance	0-50cm	0-5m (microwave)
Cost of label/tag	Inexpensive	Expensive
Standards	Defined	Being defined
Stage of maturity	Mature	Evolving

Table 2-2: RFID and Barcode Comparison (Adapted from Finkenzeller 2003)

Undoubtedly, RFID has far more capability offering more advantages than barcodes. Table 2-2 shows the differences between the two technologies. Barcode readers use optical technology to capture the patterns of a barcode label. It therefore requires a line of sight within a short distance to read the label. This inevitably calls for the need to locate a barcode label by either pointing a scanner directly at the label or by positioning the label such that it can be read by a fixed scanner. Either way involves labour. By contrast, RFID uses RF or electromagnetic waves as a means of data collection. RF works omni-directionally up to a few yards. This attribute enables an RFID reader to communicate with a tag without the need to be in the line of sight, which has an added advantage of having a reader reading multiple tags

simultaneously. This feature of RFID presents the reality of connecting the real world "with its representation in information systems" (Strassner & Schoch, 2002, p. 1). Strassner and Schoch (2002) suggest that the media break, a break between the physical entity and its information, can be avoided with automation, awareness of smart objects, and mobility. Figure 2-6 shows the progress towards the convergence of information with the use of RFID (Fleisch, 2001).

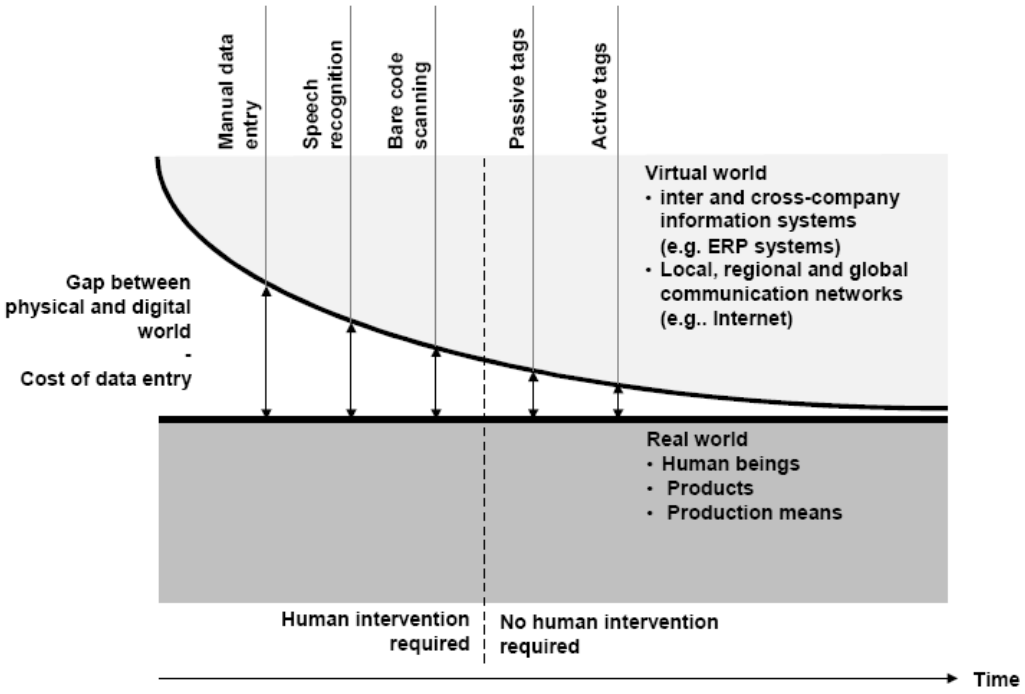


Figure 2-6: Avoidance of Media Breaks (Fleisch 2001)

The capability of reading multiple tags at a given time increases the throughput to a level that barcode cannot achieve. This also eases the bottleneck of scanning each item at a time. However, this capability has its downside. The fact that, in an RFID system, tags within range are read almost simultaneously also means that the exact sequence of the cartons is not picked up by the reader (Bednarz, 2004). In a conveyor setup, cartons are often required to be routed

to different locations. It is therefore important to know the order of the cartons in order to direct them to the right locations. Barcode systems have been successful in such a scenario. A "bar-code-based system knows more about the order of packages moving along a belt" (Bednarz, 2004, p. 8).

An advantage of RF is the ability to communicate in a harsh environment where the barcode label is worn or covered by dust. RF is able to penetrate most types of material. However, the signal is vulnerable to metal, liquid or material with high moisture content, particularly the high frequency range. More energy or power is needed to mitigate the loss of RF propagation through those materials. There are on-going projects to overcome this drawback (Collins, 2004b).

At a mature stage of development, barcode is relatively inexpensive to implement for a cost-effective solution (Anonymous, 1993; Ekman, 1992). A record storage warehouse of 30,000 sq ft uses only two computers and two wand scanners to keep track of thousands of boxes of record files (Anonymous, 1993). Conversely, RFID technology is evolving steadily particularly in the supply chain area. Setting up an RFID infrastructure can be expensive and require careful study on systems integration with existing business information systems. The RFID tags make up the main outlay. Each tag cost US$5 in early 2000 down to between US$1 to 50 cents in 2004 as reported by Atkinson (2004). The cost of a tag continues to drop and it is expected that mass adoption will begin when the cost per unit reaches no more than five cents. In 2006, the five cents per tag benchmark has been achieved at an order of 100 million pieces (Roberti, 2006b). The self-regulating market forces necessitate that should prices fall to five cents a tag, the demand for tags will increase. This in turn may create a supply issue with

production capacity lagging behind demand (Sarma, 2001). It may push prices back up, thus diminishing the prospect of an earlier mass adoption of RFID technology.

Another drawback of RFID is the lack of a harmonised standard across this system. Barcode has clearly defined standards and the different standards are globally accepted and in use mainly in the retail and manufacturing sectors. In terms of a unique numbering system for item identification, EPC is one of the standards for RFID. The use of RF is posing a challenge to a globally accepted standard – clearly between Asia, Europe and the US as highlighted earlier. At present, different standards are adopted across different RFID systems operating rather independently. Manufacturers, importers and businesses trading across borders should be concerned that systems are adhering to a common standard so that they do not have to use different systems to cater for customers in different parts of the world (Atkinson, 2004).

Privacy concern is yet another issue with the use of RFID. While standards and costs are primarily technological, privacy concern is believed to be an educational issue (Twist, 2005). The public is concerned that the use of RFID as a data collection device may obtain personal information that can be intrusive in the wrong hands. RFID is just another data collection tool for keeping track of products. As Sarma (2005) points out that the electronic toll collection, a form of RFID applications with longer read range than the cheaper RFID/EPC tag, is already in use in many countries. The information in an RFID/EPC tag is encoded and does not contain information about the consumers. It adopts the Internet technology where the information in the tag is used as an address to more information about the content. The access to such further information is secured and authenticated. RFID application is also similar to the credit card system.

2.2.5 RFID in New Zealand

RFID is widely seen in retail shops for use as EAS and in modern office building for use as access control to premises in New Zealand. It has not been used in the transport sector such as for public transport ticketing. As with other railway companies, the New Zealand railway or Kiwi Rail has been using active RFID tags on railway cars for over 17 years. The active tags are used for identifying individual railway car for the purpose of assigning loads and position to the car depending on its destination. Other applications of RFID in New Zealand are the self checking-out of books at the library, order taking for equipping army personnel, and e-passport for border security to name a few (Bell, 2006; Elmes, 2005; O'Connor, 2006). On the innovative side, similar to the concept of access control is the innovative RFID enabled pet door designed for pet owner's home (Anonymous, 2010b). More recently, Air New Zealand implemented RFID passes for their frequent flyer club members (Friedlos, 2008a). The passes use the 13.56 MHz HF passive tags for identification of passengers in self check-in and boarding. Other recent trials include the National Animal Identification and Tracing (NAIT) scheme which has been carrying out trials using the LF tags on cattles and deers (McEntee, 2009), The Warehouse Limited in the retail sector (Bell, 2005), Hawke's Bay Hospital in the health sector (Anonymous, 2008b), EastPack, a kiwifruit packhouse, in the kiwifruit sector (Friedlos, 2008b), and some pockets of closed door trials in the logistics and transport, and the primary produce sectors. There have been accuracy, reliability, and efficiency concerns on the use of LF tags in the NAIT trials. The much improved UHF EPC tag would have provided a better read rate accuracy and speed of recording large herd of cattles and deers with its greater distance and multiple tags reading capability. However, the NAIT governance selected the widely used LF citing that the other higher frequency standards are not proven and accepted in the industry (Anonymous, 2010c). The Warehouse Limited and Hawke's Bay Hospital trials have unfortunately halted citing the reasons of costs and no new benefits found in their

trials. The EastPack trial was a success and it went on to implement RFID within their operations.

A search in the business directory on RFID service provider in New Zealand found less than 15 hits on three online directory services. The probably more active RFID service providers are Peacock Bros New Zealand Ltd, Times-7, SATO, Saito Group, and Tracient Technologies to name a few. These companies offer a wide range of RFID products from shipping labels, to specialised tracking systems. For examples, Times-7 is specialised in airline baggage handling systems and in sports timing, Tracient is specialised in RFID hand-held devices, and SATO is specialised in labelling.

In the governance aspect, the New Zealand Privacy Commission is concerned with the misuse of customer information collected by RFID systems.

2.3 Supply Chain Management

The philosophy that organisations do not exist in isolation has sprung the general term of supply chain. Giannakis et al. (2004) find that there is increasing literature on supply chain management in recent years. Organisations, regardless of size and business nature, will need information resources of various forms to fulfil their business objectives. Organisations therefore depend on other business entities, either within or outside of the organisations, in order to execute their functions according to their organisations' goals.

> "A supply chain is defined as a set of three or more companies directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer" (Mentzer, et al., 2001, p. 2).

A basic supply chain consists of a company and its immediate supplier and customer. These three entities form a chain or network where products and services flow from suppliers to customers, and where the smooth functioning requires adequate information flow in both directions. This is a simplistic view of a supply chain. In reality, there are intermediary suppliers and customers who are also part of the process of making the products and services. An extended view of a supply chain would include supplier's suppliers and customer's customers (Mentzer, et al., 2001). This could start as early as in the acquisition of raw material and through to the end users (Hines, 1994).

2.3.1 The Shift in Supply Chain Management

Today supply chain management includes not only physical flow management but also financial and information flow management as well as relational supply management (Cavinato, Flynn, & Kauffman, 2006). Physical flow is the actual flow of a product through a supply chain. A product is manufactured, transported and stored along the supply chain.

Manufacturing has been evolving around low-cost labour. Factories were built in South America in the 1950s, Japan in the 1960s, Hong Kong and Singapore in the 1970s, Thailand and the Philippines in the 1980s, and China, India and Vietnam in the 1990s (Cavinato, 2006). The main objective of low-cost labour is a cost-efficient manufacturing process in order to remain competitive. As companies seek to reduce production costs in the midst of increasing

competition, sourcing outside of their domestic markets for cost effective and quality suppliers has become a strategic trend.

> "This globalization of supply management has forced companies to look for more effective ways to coordinate the flow of materials into and out of the company" (Mentzer, et al., 2001, p. 3).

A global supply chain has a complex structure ranging from distance to delays in time, cultural to language differences, customs to government regulations (Magnan & Fawcett, 2006), and increasingly worrying environmental implications (Hines, 1994). To overcome these factors, Magnan and Fawcett (2006) suggest supply chain members to be integrated and connected so that the flows of products, services, finances, and information are co-ordinated.

Transportation is often the second largest supply chain cost in a company (Cavinato, 2006). Inadequate infrastructure planning has led to traffic congestion in many parts of the world. Congestion raises the cost of delivery and impacts the reliability of delivery. The increases in crude oil prices have also raised transportation costs. A key principle in minimising transportation costs is volume buying power. Volume buying results in reduced per unit transportation cost. It allows transporting low value goods over a long distance more cost effective.

> "Synergies among business units and even with other companies, as well as with third-party logistics providers, are the ways to garner this buying power strength for price efficiencies and service offerings" (Cavinato, 2006, p. 239).

Products are usually stored in a warehouse as a buffer or safety stock. Safety stock is used to buffer sudden increases in demand due to uncertainty. Warehousing has evolved into a value-added function. As a distribution centre, a warehouse provides sorting, bundling, kitting, and inventory functions. A warehouse is more efficient in performing these functions than a factory. As such, more suppliers are outsourcing warehouse functions to third-party logistics providers (Knemeyer & Murphy, 2004) such as DHL. Outsourcing's primary objective is to reduce and control costs (Lundeen, 2006). Warehouses are also used as a strategic parts centre where time-critical high-tech service parts are located and held near customers. A distribution centre is usually larger, stores goods in pallets and operates higher inventory turn-over than a strategic parts centre. In contrast, a strategic parts centre stores time critical, high value service parts, and orders are usually in pieces instead of pallets. A recent trend in warehousing is the consolidation of faulty returned parts prior to sending them to authorised repair vendors. This is called reverse logistics.

Financial and information flows are the flow of monetary and transactional information along the supply chain related to physical flow. When an order is fulfilled, the accounts department requires information about the order fulfilment in order to invoice the receiving customer. Unfortunately, there seems a lack in timely and accurate flow of order and financial information. Although there are accounting and procurement applications that assist in generating invoices, without timely and accurate information, it is often difficult to reconcile the invoices. This delays payments and affects the cash flow.

> "No ERP system integrates across business processes between buyer, seller, carrier, financial, and other support activities" (Barry, 2006, p. 248).

Information is imperative in a business process. Barry (2006) highlights that information is a viable substitute for inventory. With information about physical flows, inventory can be reduced and invoices can be reconciled since companies have visibility to their inventory in the supply chain.

Relational supply management is the management of effective relationships amongst supply chain members. Traditional supply chain management has been dominantly at arm's-length or transactional (Birou, 2006). Most buyer-supplier relationships are transactional by nature. The relationship is short term, does not take into consideration the entire purchasing requirement and cost is almost always the primary consideration (Burt, Dobler, & Starling, 2003). Nevertheless, companies evolve as they grow. A buyer-supplier relationship starts with simple communications and evolves to various forms of integration (Jilovec, 2004). As the relationship is formed, a higher degree of trust and certainty is needed. This relationship moves into collaborative partnerships (Birou, 2006) or collaborative alliances (Burt, et al., 2003). Companies cooperate to gain competitive advantage. Collaboration is especially prominent in recent years where process improvement and technology adoption involve cross-functional business units and trading partners. At the collaboration stage, although the relationship is cooperative and beneficial to all parties involved, there is always a presence of power imparity. Burt et al., (2003) highlight that power can be at either end. A buyer might not be able to switch suppliers or a supplier might have to make an investment in order to secure business from a buyer. An example is the mandate from Wal-Mart to its suppliers to implement RFID/SC by specific dates.

2.3.2 Power Disparity in Supply Chains

It is a granted fact that there is a power disparity among partners in the supply chain with the power base now shifted to the retailers (Fernie, 2004). Retailers, like Wal-Mart, have the power to drive initiatives that are beneficial to them. This section looks at the power dependency in the supply chain and highlights the benefits of each partner.

Figure 2-7: Simplified View of a Supply Chain

For the purpose of discussion, a simplified supply chain model is used as a platform to examine the key roles that are integral parts of the supply chain. Figure 2-7 shows the simplified supply chain. The figure depicts the distribution management of a supply chain showing at least three sets of companies linked for the purpose of delivering products and services to consumers. The companies are manufacturers or suppliers, logistics service providers, and retailers. In this context, the manufacturers or suppliers supply the products and services to the retailers via the logistics service providers who provide distribution and warehousing services. This simplified supply chain model presents the primary actors in the supply chain and is adequate for this discussion. It should however be noted that the

complexity of a supply chain multiplies as the supply chain expands and extends to the raw material management, which is omitted here.

The traditional supply chain typically adopted the push method where products are manufactured and pushed to the sales front. In the 1950s, products or materials were pushed through supply chains by manufacturers. Typically the manufacturers provided nationwide distribution to retail outlets (Hines, 1994). As goods are pushed downstream, inventory piles up when demand is uncertain. This results in high held stock or inventory downstream. Prater, Frazier, and Reyes (2005) suggest that this is due to fragmentation in the supply chain. Retailers replenish goods according to their sales while manufacturers push their goods through the supply chain based on products with forward-buying and other promotions. Forward buying is bulk purchasing of product at a discount (Prater, et al., 2005). Inventory is stored in warehouses or distribution centres. Davenport and Brooks (2004) suggest that a break-up in a supply chain comes about because of the lack of information among the functions in a supply chain. Managers stock up costly inventory to create buffer and slack in the system to prevent stock-out that causes disruption in their operations and lost sales.

> "The lack of information integration among supply chain functions … means that hand-offs from one part of the business to the next are far from smooth" (Davenport & Brooks, 2004, p. 9).

This has changed over decades as enterprise systems, such as the Enterprise Resource Planning (ERP) systems and EDI permit the sharing of information across organisations and through the supply chain. The sharing of information has made managers realise that their processes are inter-related and timely acquisition of sales information will help drive out

inefficiency in the supply chain. Jilovec (2004) recognises that organisations began communicating with suppliers using EDI at departmental levels in the attempt to eliminate inefficient paper documentation such as purchase orders and requests for quotation. Integration among departments within an organisation follows when the organisation realises the benefits of sharing information among related functions such as procurement, accounts payable, and inventory planning. A more streamlined process is achieved when such integration occurs at the inter-organisational level. Collaboration among partner organisations presents opportunities for advance planning and almost real-time forecasting. This requires trust[3] and open relationships in the supply chain. Figure 2-8 presents Jilovec's (2004) illustration of the different phases of implementing RFID in a supply chain.

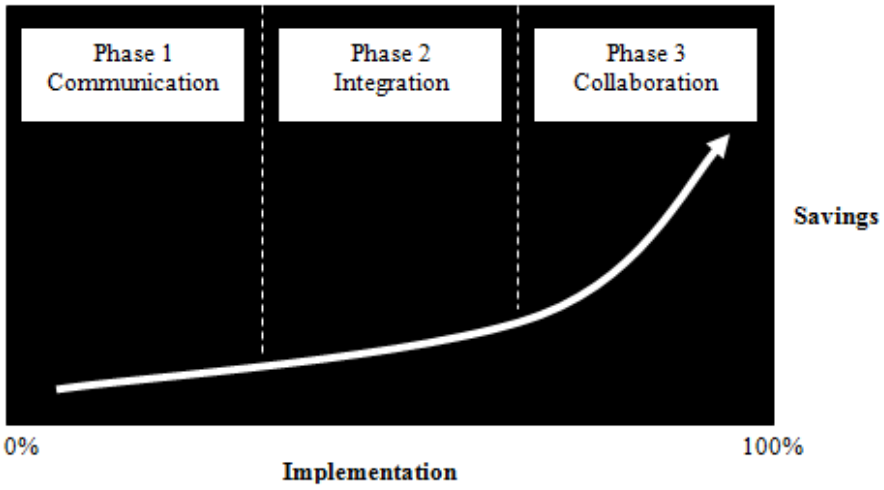


Figure 2-8: Phases of Implementation in Supply Chains (Jilovec 2004)

Inter-organisational sharing of information shifts the supply chain away from a traditional push method towards a demand-driven process (pull). The demand-side concept embraces

[3] Jilovec (2004) and Fernie (2004) write that trust is an important condition to collaborative planning.

strategies like Quick Response (QR), Collaborative Planning, Forecasting and Replenishment (CPFR), and Efficient Consumer Response (ECR). From push method to demand-side forward planning, the latter appears to afford the retailers, in place of the suppliers, more power. Retailers have gained understanding and become more conversant in the management of demand and supply over the years (Fernie, 2004; Hines, 1994). They are less dependent on their suppliers than they were in the past. For example, the adoption of ECR addresses the management of category, product replenishment, and enabling technologies (Fernie, 2004). Retailers typically have to depend on suppliers who are more product category focused and are better able to advise on product placement on shelves (Rutner, Waller, & Mentzer, 2004). However, with the ability to capture sales data on actual placement of sales, retailers can study product placement in their stores more readily and need not depend on suppliers for the information. With this information, retailers can improve their new product cycle, product ranges, and store layout (Jones, et al., 2005).

2.3.3 Supply Chain Management in New Zealand

Data from Statistics New Zealand show New Zealand is still mainly a primary produce country with dairy, meat, fruits (mainly kiwifruit), seafood as the main exporters in value term (Anonymous, 2009; Swann, 2009). Other key exporters are wine, forestry, mechanical machinery, and crude oil. Thus, New Zealand supply chains are unlike those of manufacturing focused supply chains in the more industrialised countries although New Zealand do have manufacturing plants in mechanical and electrical machinery, aircraft and parts, and pharmaceuticals (Anonymous, 2009). In recent years, manufacturing companies were looking at overseas market for the production. Fisher and Paykel’s relocation of their washing machines and dryers production facilities to Thailand is one such example.

Most of these top exports companies in New Zealand are made up of small businesses from family-owned growers to farmers. From a supply chain perspective, these groups of growers and farmers represent a large cohort of suppliers. The relationships between the suppliers and exporters are usually overcome with a larger entity managing the suppliers and packaging the goods for exporting. Therefore, New Zealand supply chains have a rather complex operational challenge from source to port. The relatively small size of New Zealand companies "make them less powerful in dealing with and in gaining compliance from suppliers and customers" (Basnet, Corner, Wisner, & Tan, 2003, p. 61). The challenge is further implicated by the strong workers union presence in the New Zealand labour force particularly when an organisation and its workers union have conflict in interests.

New Zealand is located to the southeast of Australia in the South Pacific Ocean. With land size of about 267,710 sq km, the country is divided into two islands with the north island more populous than the south island which is larger in land size. New Zealand has a longitudinal topography of 15,000 km of coastline. Fifty per cent of the land are covered by native forest and vegetation, 39 per cent are covered by pasture, and only 0.8 per cent artificial surfaces such as urban and transport infrastructure (Anonymous, 2010a). Geographically, New Zealand is distant from major markets. It has one of the longest trade route in the world (Byrne & Golden, 1994). The "dispersed rather linearly" New Zealand's population is connected by 95,000 km of one and two lanes roads and rails (Sankaran, 2000, p. 147).

There are three characteristics in New Zealand supply chains that are challenges for New Zealand companies, particularly when exporting to overseas markets. The first characteristic

is the type of goods New Zealand exports. As Statistics New Zealand shows, primary produce is key contributor to the New Zealand economy. Primary produce goods are low in value and moved in high volume. They are perishable and thus have a short shelf life compared to more durable goods. The second characteristic is the multitude of suppliers clustering at the upstream of the supply chains with mostly small businesses. There is thus extensive interaction in the supplier-customer relationship. To ensure continuity and quality in supply, retailers are adapting preferential and exclusive relationships with selected suppliers (Clements, Lazo, & Martin, 2008) creating isolations in supply chains. This is potentially harmful to the adoption of an industry wide technology where the various groups of stakeholders are to agree to a common use of standards. A good example is the NAIT scheme, in which, some form of a mandate is necessary for adoption. The third characteristic is the distance to major markets. Moving perishable goods over a long distance is subject to high level of damage and thus wastage. Innovative seems to be the key to overcome the distance barrier for New Zealand companies doing business overseas. Skilling and Boven (2007) suggest New Zealand companies to exploit the 'weightless economy' of virtual supply chains citing it "could be as transformational as refrigerated shipping was for the New Zealand economy a century ago" (p. 3). The challenge remains as the perishable primary produce is a number one contributor to New Zealand economy.

2.4 RFID in Supply Chains

The use of RFID in supply chains is an emerging technological trend that has attracted a lot of attention in the U.S., Europe, and Asia. Uptake of the technology is largely driven by the potential benefits that RFID is perceived to deliver, particularly in the area of enhancing supply chain visibility (Jones, et al., 2005). Added incentives that come alongside include

retailers reducing stockouts, distributors improving shipping accuracy and reducing inventory and labour costs (Angeles, 2005; Rutner, et al., 2004; Spekman & Sweeney-II, 2006). Spekman and Sweeney-II (2006) add that manufacturers could benefit from the elimination of chargeback for products that were not recorded as received by retailers. Deliveries are authenticated at a higher level of accuracy and thus human error in counting can be prevented. Furthermore, the sharing of product flow information would enhance the efficiency of the supply chain (Karkkainen, 2003), an important attribute of total visibility.

Major retailers and leading corporations around the globe are already testing and implementing RFID, and claiming to have achieved competitive advantage and return on investment (Roberti, 2006a, 2007b; Wasserman, 2005). Retailers such as Wal-Mart and Tesco have mandated that their top suppliers adopt the technology (Anonymous, 2003c; Roberti, 2003) and this has helped accelerate the global use of RFID.

RFID/SC has been labelled a disruptive technology (Dietz, Lemond, Moffatt, & Pak, 2006; Sheffi, 2004; Spekman & Sweeney-II, 2006). The adoption path has been likened to that of mini-computers in the late 1970s and Internet applications in the late 1990s in Walt (2005). The author suggests three steps to harnessing RFID/SC as a disruptive technology (Soon & Gutierrez, 2009). The key is in evaluating an organisation's processes and values with that of its intermediaries that might hinder the adoption of RFID. Part of the evaluation is to look at the motivation and ability of an organisation to adopt RFID. The most sought after benefit of RFID/SC is the provision of real-time information about a product. The information provide visibility and traceability capability which is what the industry has been longing for.

However, the Vijayaraman and Osyk (2006) survey[4] reveals that the lack of foreseeable benefit, cost of implementation, lack of funding, and lack of agreement on standards are some of the main constraints of adopting the technology. The most frequently cited barriers in RFID/SC articles are standards (Atkinson, 2004; Twist, 2005), cost (Niemeyer, Pak, & Ramaswamy, 2003; Twist, 2005), reliability (Alu, et al., 2006; Angeles, 2005; Smith, 2005; Twist, 2005) and privacy concern (Good, et al., 2004; Jones, et al., 2004; Kelly & Erickson, 2005). Thus, like many new technologies or supply chain concepts, RFID/SC, while promising, has some uncertainties. For example, RFID/SC is perceived to improve product visibility along supply chains but there is a perceived lack of agreements on the standards for adoption. Lin, Chiu and Chu (2005) suggest there are drivers and enablers that could be assigned to the successful implementation of an agile supply chain. Similarly, there are benefits and barriers in the adoption of RFID/SC. This section first investigates the benefits and barriers of using RFID/SC and then discusses the adoption of RFID in New Zealand supply chains.

2.4.1 Benefits of RFID in Supply Chains

Being an early adopter of ECR, Wal-Mart is now driving the adoption of RFID/SC as the enabling technology. With a better, real-time information about their actual products placement of sales, using RFID is a big incentive for Wal-Mart – RFID/SC may further increase retailers' power in the supply chain by enabling the collection of actual sales and products visibility data in the supply chain (Jones, et al., 2005). Retailers may use this

[4] The majority of the respondents are manufacturers and distributors. Only eight per cent are retailers.

information to insist on retail-ready display cases of various sizes which suppliers may find labour intensive to conform to the request. This means increased labour for the suppliers.

Besides having more control over replenishment and category management, retailers stand to gain from reduced shrinkage, stock-outs, phantom inventory, and increased inventory turns (Twist, 2005). A T Kearney highlights that retailers experience more benefits than manufacturers through reduced inventory, labour and out of stock reduction (Anonymous, 2003a). This is supported by the Vijayaraman and Osyk's (2006) survey, which reveals that retailers are expecting a positive ROI while manufacturers are pessimistic about their initial investment in RFID/SC. The survey also finds that the majority of RFID/SC implementations are focused at the warehouse level. Shipping and receiving are two popular areas where benefits are perceived. The survey confirms the distribution of benefits in this order and is depicted in Figure 2-9; retailers stand to gain more benefits followed by logistics providers, distributors, and manufacturers. With the general perception that retailers stand to gain more, what benefits do logistics service providers and manufacturers/suppliers get from RFID/SC?

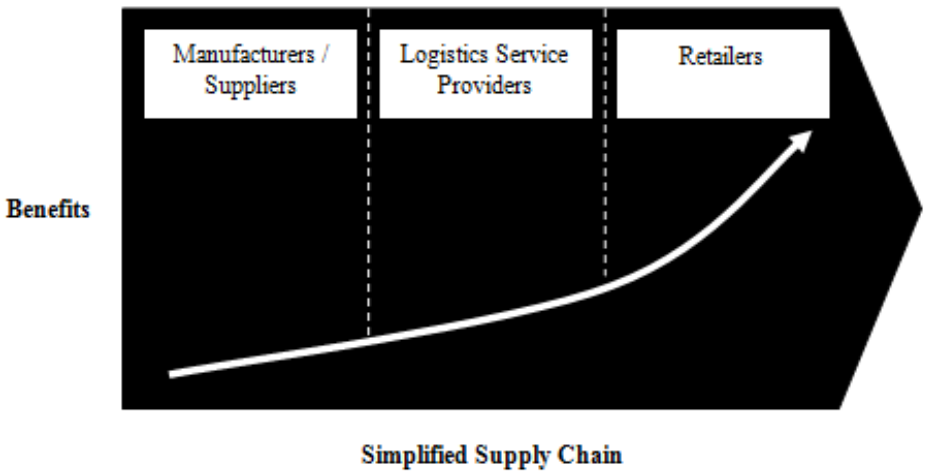


Figure 2-9: Perceived RFID/SC Benefits in Supply Chain (Adapted from Jilovec 2004)

Labour cost savings have been perceived to be the most savings in warehouses and distribution centres. This is because RFID/SC permits the authentication of products received and issued without much human intervention and in a much more convenient manner. A conventional receiving procedure involves verifying products at the receiving dock against some shipping documents. To do this, a warehouse operator has to visually match the product part number and quantity against the document. Upon verification, the operator has to carry out system transaction to complete the receiving task. This procedure can be simplified with RF readers installed at the receiving dock to scan the inbound goods and the RFID/SC system automatically matches the result with electronic shipping documents (or advanced shipping notification) received prior. The warehouse operator will just need to visually check for any in-transit damage to products and move products to their assigned bin locations. Although there are speculations of improved inventory accuracy in storing and picking functions (Jones, et al., 2005; Rutner, et al., 2004), it should be cautioned that this requires a lot more investment to set up RFID-enabled pallet and shelving positions, and other infrastructure investment that goes with it, such as RFID-enabled material handling equipment. This will only be economically viable when item-level tagging is practical and when the product is of high commercial value. Its benefits will be a more accurate inventory, reduced shrinkage and theft, and more efficient use of storage space (Jones, et al., 2005). At the outbound operation, products can be picked and loaded onto assigned trucks similarly reducing labour intensive tasks, such as the scanning of each case with a barcode scanner, and manually charging out products from the Warehouse Management Systems (WMS).

Manufacturers and suppliers have been looking for a positive ROI as Vijayaraman and Osyk (2006) report. Most respondents to their survey implemented the technology to comply with

the RFID mandate. The bulk of the investment falls on the manufacturers. Besides investing on the infrastructure, the manufacturers have to incur costs to tag products. It is financially not feasible to tag at item level when each tag costs more than five cents – especially on low-cost items. A T Kearney identifies two groups of manufacturers, the high-impact manufacturers where their transaction volumes are low and of high value, and the low-impact manufacturers with high volume but low value. The latter has a harder time justifying the investment given their dependence on individual sales transaction information from supply chain partners. The high transaction volume for this group means more tags are required, resulting in higher tagging cost (Anonymous, 2003a). Examples of low-impact manufacturers are the dry grocery and frozen foods, and of high-impact manufacturers are electronics and high fashion. The low-impact manufacturers, also known as contract logistics in the supply chain, generally fulfil the orders in pallets and have higher inventory turns than the high-impact manufacturers. Because of the high volume, it is difficult for the manufacturers or suppliers to track stocks and keep inventory. They have to depend on the retailers for the information, often which can be difficult to obtain as retailers may not share them readily. Also, most contract logistics goods are low in value, and so it is desirable that low-impact manufacturers use RFID/SC at the case or pallet level to achieve a positive ROI.

Still, there certainly are benefits that the manufacturers and suppliers can reap from the technology, such as increased inventory visibility, labour efficiency, and improved order fulfilment (Anonymous, 2003a) although they are more visible to their outsourced distribution partners or logistics service providers. Spekman and Sweeney-II (2006) add that manufacturers could benefit from the elimination of chargeback for products that were not recorded as received by retailers. Deliveries are authenticated at a higher level of accuracy and thus human error in counting can be prevented. The dilemma that most manufacturers

face is the different standards that their various partners would use. The concern is valid when manufacturers supply their products to multiple customers.

> "It is difficult for most companies to commit substantial resources required if they do not know whether their suppliers and customers will be using a compatible technology" (Twist, 2005, p. 229).

Without a doubt, many manufacturers and suppliers would want to see more benefits from RFID/SC before taking the plunge; more research is needed on this subject, in particular, at the upstream of the supply chain as shown in Figure 2-10.

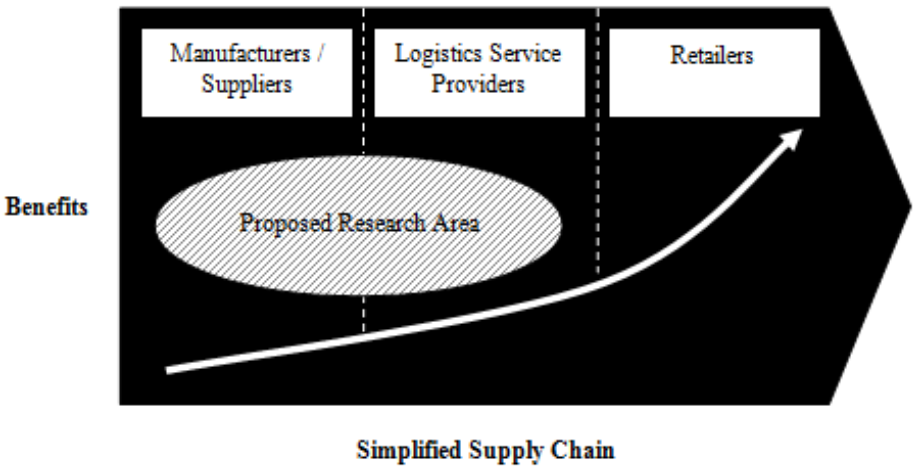


Figure 2-10: A Proposed Research Area to boost the Benefits of RFID/SC (Adapted from Jilovec 2004)

For now, the benefit of RFID/SC is perceived to be more apparent at the downstream of the supply chain. This is one of the reasons why powerful retail giants are keen to drive the implementation upstream (Jones, et al., 2005). Wal-Mart's mandate to suppliers to implement RFID/SC is one such example. It can be seen as a catalyst to the adoption of RFID in the

supply chain. The next section discusses four main barriers to RFID/SC adoption and analyses the effects of RFID mandate.

2.4.2 Barriers to the Adoption of RFID in Supply Chains

The following sections discusses the four barriers commonly are pointed out in the RFID/SC articles. The four barriers are standards, costs, reliability, and privacy.

2.4.2.1 Standards

The use of the ISM radio bands for RFID has posed a challenge to the global supply chain. Radio spectrum resource is limited and controlled by the governments in different countries (Michael & McCathie, 2005). There is a need to align the frequency usage for RFID so that the RFID system can interoperate in different countries. The worldwide use of the ISM bands for other wireless applications and the lack of restrictions to the type of applications used have made it challenging to find a slot in the band for the international alignment of RFID. For instance, today, it is not uncommon for any one piece of equipment to structurally integrate different technologies, each of which could be adopting different frequency band(s) and/or standard(s). And yet in its entirety, the equipment operates seamlessly. An example of such an equipment that adopts multiple standards that work in unity is the Subscriber Identification Module (SIM) card on any GSM compliant mobile phone (Bhuptani & Moradpour, 2005). In order to collect information of an item transiting in a global supply chain, there is a need for a distinctive coding not already adopted by any equipment in transit. This is so that there is no interference between the different frequency bands and standards when operating in the same environment. Of utmost importance is the need to ensure the integrity and accuracy of collected information.

Standards are applied to the reading of RFID tag and decoding the EPC of an item. Beneath this simple process are a number of standards: the reader and tag interface protocol, EPC numbering structure, data encryption method, etc. To ensure that RFID and EPC work seamlessly and effortlessly, there is a need to agree upon a single standard or a set of standards which is lacking in general consensus.

2.4.2.2 Costs

There are various cost factors when implementing RFID/SC. Besides the cost of the tag, infrastructure setup, systems integration, and training, there are other costs that might be incurred in the course of implementing RFID/SC solutions (Smith & Konsynski, 2003). As with any emerging technology, where there is still a lot to be uncovered, it is not surprising that many companies will find it a daunting task to calculate the true cost of implementing RFID/SC to justify a business case and return on investment. A dramatic drop in the cost of tags (as was speculated) – and five-cent (USD) per unit looks to be an economically viable unit price (Sarma, 2001) – will be much welcomed. Sarma (2001) illustrates the steps toward achieving the five-cent goal. He carefully highlights the plausible issues of capacity constraints and price-elasticity. The need to redesign and develop manufacturing processes and machines will certainly delay the fabrication of the tags in high volume (Sarma, 2001). While efforts are visible to bring the cost down, companies with high inventory turnover are going ahead with pallet or carton tagging to reap some benefit and return on investment (Smith, 2005). It also makes economic sense to tag on high-value items. However, deploying RFID simply to capture what barcode is doing does not add much value (Murphy-Hoye, Lee, & Rice, 2005). Murphy-Hoye et al. (2005) suggest the key to a positive return on investment

is detailed process mapping of the operations and linking the processes and performance metrics. Walt (2005) suggests addressing the impact of RFID adoption on a company's marketplace, business strategies, and operating model.

The empirical survey by Vijayaraman and Osyk (2006) shows that companies already pilot-testing RFID/SC find that the cost of the tags, hardware, and the availability of these components are the main issues surrounding implementation of the technology.

2.4.2.3 Reliability

The unreliable RFID read-rates hinder the adoption rate and dampen the confidence of users. Smith (2005) reveals that at pallet and case levels, the read-rate reliability was less than 80 per cent as reported by the suppliers who were preparing to comply with the Wal-Mart mandate. Another issue is the massive amount of data collected. Angeles (2005) reveals that there was a 30 per cent increase in the amount of data when RFID is tagged at pallet and case levels. Companies will have to determine the level of data integrity, or the granularity required, and employ middleware to filter and manipulate the data. The computer network will still have to be able to handle the increased huge data traffic to avoid downtime that could affect other applications, and the databases used will have to be robust and scalable to handle the data volumes.

Another reliability issue is the interference of RF. Alu et al., (2006) in their experiment conclude that the reliability of the reader is dependent on the electromagnetic environmental conditions and structures. They note that "when the reader is in the presence of typical noise spikes the energy range is much shorter than the case in which the reader is in a typical

outdoor environment" (Alu, et al., 2006, p. 106). Every environment has a different amount of RF pollution and therefore it is recommended that site surveys be conducted on the physics of the environment (Spekman & Sweeney-II, 2006). In addition, it is recommended that different types of tags be tested on different products to ensure that the interference caused by the product properties are minimal (Smith, 2005).

2.4.2.4 Privacy

While standards, cost, and reliability issues are non-market related and technical, privacy concern is seen as an educational issue both internally and externally, with the need to involve the relevant legislative authority. Twist (2005) suggests that consumers need to be educated and informed of the new technology. He counters the preconception that personal information will be tracked through RFID by arguing that retailers are already using information collected from credit-cards for forecasting sales and buying behaviours. RFID/SC is simply another data collection tool for tracking only the flow of an item. Sarma (2005) draws attention to privacy violation in other RFID applications such as electronic toll collection, which in fact has a much longer read-range. He argues that EPC is designed to be simple with minimum functions, and thus, inexpensive, adding "EPC has safeguards to protect the consumer" (Sarma, 2005, p. 49). Other advocates of privacy raise the importance of legislation to protect consumers and assert that the retailers are to abide by the public policy (Jones, et al., 2004; Kelly & Erickson, 2005). EPCglobal has issued guidelines on EPC for consumer products. The guidelines in brief state that consumers are to be given clear notice of the presence of EPC on products they purchase and the choice to discard or remove the EPC tags. EPCglobal assures consumers that EPC "does not contain, collect or store any personally identifiable information" (EPCglobal, 2005b).

2.4.3 The Effects of the Mandate and the Wait-and-See Strategy

RFID/SC became widespread when large retailers such as Wal-Mart and Metro announced their mandates for its suppliers to adopt RFID when delivering orders to them. At the stage of the mandates, there were no agreements on the RFID standards. Thus, there were uncertainties among the suppliers in what RFID systems to adopt, how to implement, and which RFID vendors to work with.

At that current stage of RFID/SC adoption, two groups are identified: companies with the mandate to implement RFID/SC in order to continue business with retail giants and companies not affected by the mandate and, who were either adopting the wait-and-see strategy or planning to adopt the technology. The reason for classifying as such is that there is a clear division between the groups in terms of their positions in adopting the technology. For now, the main distinction between the two groups is whether or not there is a mandate that pushes for RFID adoption. The mandate could take a toll on smaller suppliers; while those wait-and-see companies would risk losing market share should RFID/SC take off. Both groups face a challenge of implementing a relatively new technology that has very few preceding examples to learn from.

A recent use of mandate to drive adoption of technology was enforced by governments relating to the use of EDI (Clarke, 1994; Udo & Pickett, 1994). Mandate was then used as a binding obligation issued by a large authority. In the EDI mandate, the governments have issued the mandate to use EDI as a platform for electronic transfer of data. While larger companies were willing to accept EDI, smaller companies were unable to justify the

investment costs of implementing EDI due to limited budget (Udo & Pickett, 1994). Similarly, the mandates to suppliers to implement RFID/SC come from large companies such as the United States Department of Defense, Wal-Mart, Tesco, and Target (Jones, et al., 2005; McFarlane & Sheffi, 2003), as an ultimatum to adopt RFID in order to continue their business relationships. Thus mandate is used as a strategy by large companies to drive their companies' initiatives on technology adoption (Humphreys, Lai, & Sculli, 2001). The rest of this section looks at the possible effects of RFID mandates on businesses and discusses issues that managers should be aware of when embracing RFID/SC.

2.4.3.1 Effects of the Mandate

For a comprehensive analysis, the effects of the mandate are considered in three tiers. The first tier is the immediate impact as companies hurried the adoption of RFID/SC to comply with mandates. The action creates challenges as it develops. The second tier ensues when the first tier suppliers have implemented the technology and begun to focus on the operational and tactical issues of sustaining the technology. At this level, managers are faced with integration issues. The third tier is the post RFID/SC challenge. The aftermath in the long run may change the way the supply chain operates, and introduces new processes. The rest of the section discusses the effects.

Since the announcement of the RFID/SC mandate, the supply chain world has been teeming with the largely unfamiliar RFID technology. This is the start of the first tier of the effects of the mandate. The foremost impacted suppliers are those key trading partners to the retailers, reasonably large in organisational size. The initial outlook of those who adopted the technology in compliance with the RFID mandate was not very optimistic (Vijayaraman &

Osyk, 2006). They are not as yet confident in the technology of which they have little knowledge and limited funding. They report a lack of foreseeable benefits matched against high costs with unsatisfactory results in their pilot tests. The poor results are due to the unavailability of hardware coupled with technical issues such as read rate and reliability (Vijayaraman & Osyk, 2006). While the technology is maturing, the sudden rush to comply with the mandate has increased the demand for hardware, including the tags, and middleware. The industry is simply not prepared for the mandate and to meet the demand for hardware and software. While undergoing the first tier effects, the suppliers are subjected to technical challenges and continuous struggles in finding a business case in the effort to stay in business with the retailers. This issue is more obvious within contract logistics or the low-impact manufacturers. Nonetheless, if that one retailer is a key source of revenue for the supplier, it may be justifiable to comply with the mandate to retain the customer or even for the organic growth of the whole. To find a stronger business case, companies have to expand the implementation beyond simply complying with mandate requirements (Rutner, et al., 2004).

> "Where implementation seems to progress well is when firms move beyond simple compliance in logistics and extend the use of RFID into other areas of their operations" (Spekman & Sweeney-II, 2006, p. 738).

Moving on to the second tier, suppliers who have now implemented RFID/SC will start working at integrating the technology into their existing enterprise systems. In complying with the mandate's deadline, suppliers might not have the resources and the knowledge well in advance to design a full integration of the technology and might only be ready to integrate at the WMS level. Vijayaraman and Osyk (2006) comment that most suppliers did not envisage a higher level of integration with their overall IT strategy and Kommareddi (2005)

estimates that 90 per cent of retailers implementing RFID are not incorporating business intelligence infrastructure or analytical systems to analyse and synthesize the data captured by RFID. This means that the initial implementation for many in the supply chain will need to be reworked within the organisation to fully integrate all relevant information systems. Companies without a scalable network infrastructure will likely have to incur additional costs in redesigning the network to cater for additional hardware and data traffic capacity.

On top of the impact on existing systems and infrastructure, business processes and values are also affected. RFID/SC introduces efficiencies to logistic processes and in order to benefit from it, companies have to educate and train their employees to use the new technology and to execute changes to their business processes. For example, an RFID tagged pallet has to pass through a reader. This can be problematic for multi-client warehouse where employees usually handle multiple systems and processes; using different hardware. At the management level, managers may be busy figuring out what to do with the data collected. The use of analytical tools will help as Kommareddi (2005) urges. It is also noted by Craig and Tinaikar (2006) that most companies, when designing their IT infrastructure, do so based on their existing capabilities with the objectives of improving the current service levels and costs. As such, it is often perceived that IT is incurring costs. Craig and Tinaikar (2006) argue that IT investment should also be driven by generating revenue, with creating strategic advantage as the long term goal. This foresight allows managers to invest on a scalable infrastructure that should be aligned with their corporate strategies, thereby putting forth a highly justifiable business case.

New ways of supply chain operation start to kick in when RFID/SC is integrated into the enterprise systems. This is the beginning of the third tier of the mandate effect. Overtime,

warehouse operations will define new approaches and configurations. As inventory turnover improves and products spend shorter time in storage, cross-dock activity becomes more important (Twist, 2005). Cross-dock allows efficient movements of products by eliminating the need to keep the products on the shelves. This indeed has insightful implications for the design of a warehouse. The proportion of storage and working areas may change. The design of storage racks may need new configurations to suit cross-dock activity. This in turn may affect the way material handling equipment is used. New customers are likely to take a longer implementation time given the added complexity of systems integration. Retailer and supplier relationship at this stage moves to a higher level of collaboration and there are likely to be more interactions between them. The interactions form a closer, long-term relationship that ties both parties to strive to make the relationship work. New players may find it difficult to enter the market.

The three-tier effects of mandated RFID adoption provide some insights for companies evaluating the technology. There are at least six important lessons learned from the early adopters' experience. First, RFID in the supply chain is a reality. Learning from these lessons, companies intending to adopt the technology should start by finding out about the technology and knowing how it fits with their supply chain. Then, put forth a business case to secure funding. Second, more benefits can be reaped down the road when RFID/SC is extended beyond complying with mandates. A T Kearney advises companies to focus on implementing the technology within their domains to yield satisfactory benefits before trying to implement across the supply chain (Anonymous, 2003a). This helps companies to focus on their core business instead of merely fulfilling immediate needs. Third, the integration of RFID/SC into the existing enterprise should be planned at the outset in the evaluation phase. This will avoid costly rework of infrastructure and minimise disruption to current operations. Murphy-Hoye

et al. (2005) suggest adopting the 'scope' approach to identify areas where RFID provides more benefits or positive impacts, and using the 'scale' approach to test and implement the technology. Fourth, management has to decide what type of information they require and how to report it. This is to avoid being clouded with massive amounts of data and caught off guard without analytical tools for meaningful reporting. Fifth, managers are to be aware of any likely shifts in their operations that might affect future development. It will be costly to redesign infrastructure such as warehouse layout, to suit new processes or to try fitting new processes into an existing infrastructure that is overly rigid. Last but not least, managers are to be aware of future relationships with retailers and suppliers so as to position their strategies well.

2.4.3.2 Wait-and-See Strategy

Many companies are waiting for signs in the industry before committing resources to adopt RFID/SC (Vijayaraman & Osyk, 2006). "Those who wait run the risk of being pre-empted and losing market share" warn Spekman and Sweeney-II (2006, p. 747). Companies not affected by the mandate might therefore want to get out of their comfort zones and start to establish for themselves a foothold with their suppliers and retailers before losing ground to the early adopters. The 'mandate effects' provide a platform for companies to catch sight of the mechanism of RFID/SC from a holistic point of view[5], an opportunity the early adopters did not have.

[5]An integrated supply chain needs to take a total system view of the supply chain (Spekman & Sweeney-II, 2006, p. 744).

2.4.4 RFID in New Zealand Supply Chains

The earlier review on RFID in New Zealand shows RFID is not new to New Zealand companies. However, the use of RFID/SC is at its early stage in New Zealand. The review also shows pockets of trials within the New Zealand supply chains with the NAIT scheme, The Warehouse Limited, and EastPack Kiwifruit trials as the more prominent ones. So what has take-up been like in the New Zealand market?

The RFID community in New Zealand is largely driven by a small group from industry, solution providers, and GS1 New Zealand. A society called The New Zealand RFID Pathfinder Group is created within this community to discuss and create awareness of RFID among New Zealand businesses. The society discusses possible implementation of RFID and organises events to educate the public about the technology. This initiative has brought businesses together and the result is a showcase of RFID implementation that is collaboration among the supply chain partners. An example of a successful implementation is the tracking of kiwifruit from orchards to sorting houses to exporting markets. EastPack, a grower owned kiwifruit post-harvest company, ships more than 12 million trays of kiwifruit every year around the world (Friedlos, 2008b). EastPack uses EPC tags to track the trays of kiwifruit as they are packed, stored, and shipped. The RFID tagged trays are handed over to Zespri, EastPack's exporting partner, for exporting the kiwifruit to overseas markets. In a trial, both organisations saw potential improvement in their supply chain efficiency and savings on perished kiwifruits as a result of faster turnover through tracking and monitoring of the kiwifruit trays (Anonymous, 2008a).

New Zealand companies have been watching the development of RFID in the early 2000s. There are many trials and experiments since 2003 on the use of RFID in the supply chain but

none has really been implemented at an organisational level. The earliest large scale trial using RFID was possibly the NAIT scheme and arguably the most important one for New Zealand economy. This is because dairy and meat are by and large New Zealand's biggest exports. The trial was primary for the tracking of live stocks related to both dairy and meat production (Anonymous, 2005). It was intended to be extended into retail stores of a supermarket chain (Bell, 2004a). In the retail industry, The Warehouse went public with their RFID pilot trials in 2006 (Swedberg, 2006b). There was no further public announcement of extending the trials into their stores. It was understood that the trials were halted due to the costs and lack of foreseeable benefits in using the technology. In the transport industry, Toll Rail New Zealand has been using RFID to track their rail vehicles and for inventory control (Anonymous, 2006) while New Zealand Post had some thoughts of using RFID (Bell, 2004a).

The general feel of RFID adoption in New Zealand is that there are pockets of small-scale trials by leading companies in New Zealand. Most of which are closed loop and within a restricted operations area. Although there is increasing interest in the technology and the number of solution providers is growing, most companies are taking a back-seat when it comes to adopting the technology. Surveys conducted in 2006, 2007, and 2008 on RFID showed there was not much change to the investment plan by businesses across New Zealand (iStart, 2006, 2007, 2008). An average of 10 per cent of the respondents was reported with the intention to invest in RFID. Analysts were predicting an adoption rate of 20 per cent and about a 60 per cent increase to the budget for RFID (Jones, 2006; Klein, 2006).

There seems to be having many problems in the use and application of RFID in supply chains. The adoption rate of RFID in New Zealand is low when compared to other regions. In the following section, technology adoption models are discussed.

2.5 Technology Adoption Models

Tornatzky and Fleischer (1990) describe technological innovation as two set of processes performed by individuals, groups, and organisations: "there is one set of processes that deal with the creation, nurturing, and delivery of new technologies ... and another set of [processes] concerned with adoption and use" (p. 28). This research is focused in technology adoption; the second set of processes that are concerned with adoption and use. This section looks at

In the technology adoption literature, there are various levels of technology acceptance. They can be categorised into individual technology adoption and usage, and organisational technology adoption and implementation.

In the individual technology adoption and usage literature, most studies looked at the antecedents of individual behaviour in relation to information technology acceptance. Individual behaviour that has an effect on beliefs and attitudes forms the underlying principle of individual technology adoption theories. The models are constructed around users' perceived attributes of an innovation (Gallivan, 2001) and at a later stage a formation of intentions to adopt and use the innovation (Agarwal, 2000). An early model on individual technology adoption is derived from Fishbein and Ajzen (1975) work on Attitude theory or more commonly referred to as the Theory of Reasoned Action (TRA) by more recent literature. The theory posits that behavioural intentions are influenced by an individual's attitude and subjective norm about performing a behaviour. Attitude is a collection of perceived attributes of an innovation, or evaluations of performing a task in relation to other

constructs, beliefs and consequences. Subjective norms are normative beliefs of performance or non-performance. It is the individual's perceived attributes of certain referents that influence the behaviour to perform or not to perform. Two assumptions of the TRA have received constructive criticisms from fellow researchers. First, the assumption of beliefs, both normative and attitudinal, is uncertain "because it is difficult to distinguish the direct effects of norms on intentions from indirect effects via attitude" (Agarwal, 2000, p. 88). The second assumption is that attitude may influence the formation of beliefs. Once an intention is formed, individuals are more likely to perform the behaviours. As a result two other widely tested acceptance theories were developed: Technology Acceptance Model (TAM) and Theory of Planned Behaviour (TPB).

The simpler TAM posits only two beliefs: perceived usefulness and perceived ease of use. Fishbein and Ajzen (1975) "view most social behaviour as being volitional, barring unforeseen events, a person should perform those behaviours he intends to perform" (p. 15). Unfortunately, in reality, there are constraints particularly those beyond the control of individuals that may limit the performance, or lead to the non-performance of behaviours. Fishbein and Ajzen (1975) do recognise that performance of an individual may depend on other individuals' actions. They suggest that the individual may change her attitude once she realises that she is unable to perform the behaviour in question. They found that lack of ability is the only factor that breaks the relation between intention and behaviour. That is, people do not intend to perform behaviours that are beyond their ability. Therefore if a control measure is taken account for the ability to perform a behaviour, a person's intention may predict her behaviour. The TPB introduces such a control mechanism that measures the influence for performance and non-performance. The perceived behavioural control "reflects an individual's perceptions that there exist personal and situational impediments to the

performance of" a behaviour (Agarwal, 2000, p. 87). With these two impediments in mind, the TAM and TPB are studied and dissected for relevant constructs that are useful to this research.

While TAM and TPB explore the attitude and behavioural intention of individual in using technology, another group of researchers explore the productivity of using the technology. Goodhue (1995) proposes the use of Task-Technology Fit (TTF) model to assess the suitability of a technology with the tasks it is intended for. Goodhue (1995) suggests that by matching the technology functionalities with the task requirements, performance of individual using the technology will improve. Hence, TTF are studied to explore how RFID can be applied in supply chain management.

In the early organisational technology adoption literature, Zaltman, Duncan, and Holbeck (1973) suggest that technology adoption took place at the organisational level before individual usage. Usually, an organisation makes the decision to adopt a technology and cascade the adoption to individual users. In their study, Zaltman et al. (1973) examined technology adoption as contingent on a prior event, thus making it a two-stage adoption model. Tornatzky and Fleischer (1990) suggest there are many sub units that participate in technology adoption and decisions are made by individuals, groups, and even organisations. There are also higher levels of hierarchy in a social systems where technological innovation takes place; interorganisational links, aggregates of organisations, and societies (Tornatzky & Fleischer, 1990). Thus, Tornatzky and Fleischer suggest the use of Technology-Organisation-Environment (TOE) framework for a wider coverage of technology adoption behaviour at organisational level.

In more recent literature, the study on organisational technology adoption suggests "the most common pattern within organisations is a consensus-based primary adoption decision (at the management level), followed by authority-based secondary adoption ... mandated adoption at user level" (Gallivan, 2001, p. 54). A widely referenced work is Rogers' (1995) work on the diffusion of innovations (DOI). Rogers (1995) suggests five factors that are consistently found to be significant in most seminal literature.

The above discussion clearly defines two stages of technology adoption. Regardless of the level of involvement, the stages can be defined as, the initial decision to adopt or not to adopt technology, and the actual usage of the technology after the decision to adopt it has been taken. In certain literature there is a third stage – the implementation stage (Gallivan, 2001; Rogers, 1995). Gallivan (2001) finds in the IS literature that most studies focus on adoption rather than the actual implementation. He argued that at the organisation level, it is how extensively the innovation is used and diffused in the organisation's processes, structures, and culture that matter. Although this research is primarily focused on the initial adoption decision of an organisation to adopt or not to adopt RFID, it is important to extend the study beyond the implementation stage. The reasons for doing so are because RFID implementation involves more than one member in a supply chain and organisations look at long term investments that are usually extended beyond implementation. The ability to track items along supply chains suggests RFID implementation is a cross-organisational implementation, or the interorganisational links. The fact that organisations were unable to find a business case for RFID use suggests that a wider extent of implementation – across multiple operation areas – is desired.

It should be pointed out that although stage approach to innovation study is commonly pursued in literature, research also shows that innovations do not necessary follow a single set of stages (Tornatzky & Fleischer, 1990). While stage approach provides a form of structure for studying organisational technology adoption, one should note that innovation is often not linear and organisations are often faced with resource and capability challenges in implementation. Christensen, Anthony, and Roth (2004) propose the Motivation/Ability Framework (MAF) to assess the ability of organisations and identify their positions in terms of their motivational and ability strengths.

The following sections discuss the two branch theories of TRA, the TAM and TPB. Understanding of the TAM and TPB provides a foundation to other acceptance theories especially those modified from these theories. TAM and TPB, and notwithstanding TRA as their origins, have become fundamental to many technology acceptance frameworks. This is followed by the discussion of TTF, DOI, MAF, TOE framework, and a comparison of the models. Thus, the discussion of the technology adoption models in the following sections moves from the individual to inter-organisational technology adoption models. Together, they provide a framework that guided this research.

2.5.1 Technology Acceptance Model

In the study of technology acceptance, Davis' (1989) TAM is one of the most frequently cited theories in the IS literature. As it is branched from the TRA, TAM's underlying assumption is that attitudes predict intentions. Intention is therefore a dependent variable which can be used to predict future behaviour in the IT domain. Davis, in the development of TAM, discusses various constructs that are important to forming the beliefs of a given behaviour. His work is

based primarily on individual's evaluation of how the use of technology improves ones work productivity. The results are two general constructs that explain the self-reported current use of the technology in his study; however, one was more strongly linked to usage (Davis, 1989). The two constructs are Perceived Usefulness and Perceived Ease of Use. Both the constructs explain the attitudes, or affective belief (Agarwal & Prasad, 1997), toward the usage of IS.

Perceived usefulness is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). It is a measure of the extent the person believes that the use of the system will help her improve her job performance. Perceived usefulness is linked to job performance of the system evaluator as found by Davis (1989) in Schultz and Slevin (1975) and Robey (1979). The motivational aspects of using a system were also described as part of the perceived usefulness in TAM. It includes the expectancy of the benefits of using the system such as job satisfaction through enhanced self-effectiveness on the job and increased productivity.

Perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). This is the measure of how easy or how difficult it is to use the system as distinct from the benefits of using it. In other words, an easier to use system is more likely to be accepted by users. According to Davis (1989), perceived ease of use is supported by Bandura's (1982) work on self-efficacy. It is the determinant of usage and the determinant of outcome beliefs, and thus user's behaviour.

Davis (1989) also draws on the cost-benefit paradigm to explain that perceived usefulness and perceived ease of use could help solve the poor performance in decision making. Perceived usefulness and perceived ease of use provide the subjective aspects of performance and effort

respectively in decision making. In his findings, Davis (1989) reveals that usefulness was more significantly correlated to usage than ease of use was. He explains that it makes sense that users are driven firstly by the functions of an application and secondly by how easy it is to use the application. It also makes sense in the cost-benefit decision making at the organisational level. In most cases of technology adoption, one of the primary objectives is to solve a business problem, thus the usefulness of the technology is important. The ease of using the technology is secondary. It was also discovered that ease of use becomes less significant as users use the systems. Davis et al. (1989) point out in their work that behavioural intention to use a word processor diminished as users learned to effectively operate the application. Szajna (1996) supports this notion in her work on the usage of electronic mail system. Hers and other studies (Igbaria, Zinatelli, Cragg, & Cavaye, 1997; Mathieson, 1991) also find that perceived ease of use to a certain extent explained the variance in perceived usefulness. Igbaria et al. (1997) explain that training programs may enhance users self-efficacy and improve users perceived usefulness of the system. Interestingly, their study on the acceptance of personal computing by small businesses in New Zealand shows that perceived ease of use has a more significant effect on usage than perceived usefulness has. This is in contrast to the Davis et al. (1989) study on the use of word processors. Igbaria et al. (1997) suggest a reason for the inconsistency is due to the small size of the businesses in their study. It could be that support for computing systems might not be readily available to small businesses and thus the businesses are driven by the ease of use to overcome the limited support (Riemenschneider, Harrison, & Mykytyn-Jr, 2003).

Observing the targeted audience for both studies, it is noted that while Igbaria et al. (1997) respondents were eighty per cent from middle management to non-supervisory positions,

Davis et al. (1989) audiences were MBA students. Based on this statistic, an explanation for the inconsistency could be that the MBA students were assuming a managerial philosophy when attempting the questionnaires since they are studying at a strategic level. Thus, the perceived usefulness of a system would have a greater effect on usage in a strategic context, that is, at the organisational level. The audiences from Igbaria et al. (1997) were assumed to have completed the questionnaires based on individual voluntary computing acceptance mood. Therefore, the perceived ease of use would have become more important as individuals are concerned of performing their tasks. Although not mentioned by them, the Igbaria et al. (1997) findings on the significance of management support on perceived usefulness has a higher effect on system usage than perceived ease of use has. While management could assist by providing training which could improve trainees' perception of the ease of use, management support would have more influence over the benefits of using the system. Igbaria et al. (1997) suggest enhancing the perceived usefulness to stimulate more extensive usage.

To dissect the model, the approach taken by Davis (1989) to develop the items for TAM is summarised herein. Table 2-3 shows the items that are used to measure the two constructs in TAM. It is worth noting that the items of perceived usefulness are related to the functionality of a system, that is, how effective and important the system is to function in one's job. The items of perceived ease of use are related to the degree of efforts on learning to use a system. The effect therefore diminishes over time as users learn the functionalities of the system.

Model	Variable	Category Item	Source
Technology Acceptance Model	Perceived Usefulness	Job effectiveness Productivity / time saving Importance of system to one's job	Davis 1989
	Perceived Ease of Use	Physical effort Mental effort How easy a system is to learn	

Table 2-3: Category of Items in the Technology Acceptance Model

2.5.2 Theory of Planned Behaviour

Ajzen (1991) in TPB extends the TRA to overcome its "limitations in dealing with behaviours over which people have incomplete volitional control" (p. 181). Behavioural intention is a good predictor of the behaviour in question only under the assumption of free will to perform or not to perform the behaviour, that is, the person performing the behaviour has control over her own behaviour. Ajzen (1991) suggests that most cases of performance depend upon certain non-motivational factors to some degree such as time, money, and skills. In an organisation, there are always such constraints that limit the scope of work. This behaviour control aspect of the theory is considered as the ability factor while intention is considered the motivation factor in Ajzen (1991).

The use of these two factors can elicit comparisons to the Christensen et al. (2004) MAF for innovation which is discussed in a later section. The framework suggests motivation as the market incentives to innovate, such as for profit, cost savings, and market shares. Ability in the framework is defined as the capability to turn available input into meaningful output where there is real demand. The framework posits that non-market forces affect the motivation and ability for organisations to innovate.

While the MAF can be used to identify non-market or external factors that impede adoption (actual control), the TPB explores the perceived behavioural control to predict its impact on intentions and usage. Ajzen (1991) introduced perceived behavioural control as a prediction of intentions and actions in TPB. He refers to behavioural control as the availability of resources and opportunities for a person to achieve an intended behaviour. Perceived behaviour control is the perception of the ease or difficulty in achieving the behaviour. According to Ajzen (1991), the perceived behavioural control is most compatible to Bandura's (1982) perceived self-efficacy. An assumption of perceived behaviour control and self-efficacy is that a more confident person can achieve more than a person who doubts her own ability. It should be noted that information about the behaviour or intended actions must be processed before the person has the confidence to perform the actions. Thus, perceived behavioural control has low predictability of actions if there is relatively little information about a behaviour. This remark is also true when the resources and opportunities have changed or "when new and unfamiliar elements have entered into the situation" (Ajzen, 1991, p. 185).

Therefore, the measurement of the intentions and perceived behavioural control must be in the same context as the actions to be taken. Furthermore, both the variables must "remain stable in the interval between their assessment and observation of the behaviour ... that perceptions of behavioural control realistically reflect actual control" (Ajzen, 1991, p. 185).

Two other variables in TPB have already been briefly described in the discussion of TRA. Ajzen (1991) crafted his approach to attitude and Subjective Norm variables by looking at different kinds of variables. He distinguished attitude as affective and evaluative. An affective

judgement would be the assessment of positive or negative feelings and an evaluative judgement would be the perceived costs and benefits of performing. However, when both kinds of attitudes were assessed together, there was no significant improvement to the TPB model. Ajzen (1991) in assessing Subjective Norm suggests considering personal feelings of moral obligation. He shows that the addition of perceived moral obligation further increased the explanatory power of the model. Interestingly, Ajzen (1991) finds Subjective Norm in the studies of people's intentions to engage in various activities less influential than their personal considerations. Thus moral obligation to a certain degree overshadows the perceived social pressure to perform or not to perform. Table 2-4 shows the various kinds of items for each of the variables in TPB.

Model	Variable	Category Item	Source
Theory of Planned Behaviour	Attitude	Behavioural beliefs Affective and Evaluative Perceived costs and benefits Positive and negative feelings	Ajzen 1991
	Subjective Norms	Normative beliefs Personal considerations Moral obligations Motivation to comply	
	Perceived Behavioural Control	Control beliefs Ability to act Perceived self-efficacy Past experience	

Items vary with situations and contexts.

Table 2-4: Category of Items in the Theory of Planned Behaviour

There are many studies that have compared TAM and TPB in an attempt to find a more predictive model (Brown, Massey, Montoya-Weiss, & Burkman, 2002; Mathieson, 1991; Taylor & Todd, 1995). First and foremost, TAM has been designed to predict the use of IS

and TPB has been designed to explain behaviours across different settings (Mathieson, 1991). Both theories explore the cognitive side of users to predict their intentions to perform or not to perform. While TAM's constructs are simple and easy to apply, it is tested mainly on IS usage. TPB, on the one hand, is applicable to various situations; on the other hand, it is more complicated than TAM in that the researcher has to be familiar with the context of the research.

TAM specific design to predict the use of IS by an individual voluntarily, is a powerful model to assess the use of IS in a setting where the individual has the free will to use or not to use the system. It is therefore a good predictive model for assessing the success of an IS application in terms of performance and user's adoption of the IS. TAM, however, does not explicitly measure the social aspects of performance. Davis et al. (1989) explain that social influence – Subjective Norm – is less significant in explaining a behaviour where the intention to use a system is personal and individual. Subjective norms would also have indirect effects on behaviour through attitude and thus are not independent of outcomes (Davis, et al., 1989). That is, "social norms will already have been taken into account to some extent in the evaluation of outcomes" (Mathieson, 1991, p. 178). With the exclusion of Subjective Norm from the model, it is unclear as to whether the attitude towards a behaviour is influenced by social effects, or external control. TPB with a contextual set-up could capture the social effects of a given behaviour in the study. Nevertheless, the social effects are specific to the context. For example, Ajzen (1991) suggests that perceived moral obligation was predictive in a study of three unethical behaviours: cheating in a test, shoplifting, and lying. Similarly in the behavioural control aspect, TPB's perceived behavioural control, specific to context, is adequate in explaining the resources and opportunities of a performance, provided it is specific and accurately recorded by the model. Control factors can

be categorised as internal and external (Ajzen, 1985; Mathieson, 1991). Internal control factors are individual's characteristics such as skills and will power whereas external control factors are from outside sources such as time, opportunity, and cooperation with others (Mathieson, 1991). According to Mathieson (1991), TAM's ease of use explains the internal control but is lacking the external control aspects of IS usage. Both Brown et al. (2002) and Taylor and Todd (1995) find that Subjective Norm and perceived Behavioural Control explain variances in intentions better than TAM and provide more insights. Harrison, Mykytyn-Jr, and Riemenschneider (1997) also find strong support for the TPB in their study of new IT adoption by small businesses. However, TAM is still the preferred model to predict IT usage for its simple, lower cost approach (Taylor & Todd, 1995). Table 2-5 shows the summary of the key items in the decomposed TPB model proposed in some studies for a more predictive IT adoption model.

Model	Variable	Category Item	Source
Decomposed Theory of Planned Behaviour*	Attitude	Perceived usefulness Perceived ease of use Positive and negative feelings Compatibility Productivity and effectiveness	Brown et al. (2002) Harrison et al. (1997) Taylor & Todd (1995)
	Subjective Norms	Perceived social expectation regarding adoption Peer and Superior influence	
	Perceived Behavioural Control	Hardware and software compatibility Time to implement Required training Financial assets Self-efficacy Perceived facilitating conditions Technology facilitating conditions	

*Including the combination of Technology Acceptance Model and Theory of Planned Behaviour.

Table 2-5: Category of Items in the Decomposed TPB and TAM

2.5.3 Task-Technology Fit Model

The originating authors of the TTF model operating at the individual level are Goodhue (1995) and Goodhue and Thompson (1995) and at the group level are Zigurs and Buckland (1998) (AISWorld). There are however several studies on the impact of technology and data representation on performance and the importance of fit to task requirements (Benbasat, Dexter, & Todd, 1986; McGrath, Arrow, Gruenfeld, Hollingshead, & O'Connor, 1993). As Goodhue's (1995) TTF has been widely used in the evaluation of IS, the framework is discussed here.

Goodhue (1995) examines several concepts and theories, such as TAM, TPB, job satisfaction theory and political perspective, and suggests the TTF can explain business productivity and efficiency, that is, performance. "The task-technology fit perspective suggests that a better fit between technology functionalities, task requirements, and individual abilities will lead to better performance" (Goodhue, 1995, p. 1828). Thus the underlying proposition of TTF is that performance is affected by how well technology fits the task processes. It also assumes that individuals can evaluate how well technology fits the task processes but may have no choice of using or not using the technology. Goodhue (1995) proposes four propositions in TTF – technology, task, individual characteristics as the three propositions of independent effects, and interactions between technology-task and technology-individual as the fourth propositions of interaction effects. He identified twelve variables that are significant in the evaluation of the four propositions. Table 2-6 shows the variables used to evaluate the propositions.

Goodhue (1995) finds support for the four propositions in his study of 357 respondents. The study provides two key findings. First, the evaluation of technology appears to be dependent

upon the tasks of the user. Information systems are viewed as tools which assist or hinder users in the performance of their tasks. Second, users are capable of evaluating the technology they use. It is worth noting in this study, the TTF is developed under the influence of organisational contingency theories (Goodhue & Thompson, 1995). Thus with careful evaluation, TTF can appropriately be applied to the study of technology evaluation by individuals at the organisational level.

Model	Variable / Proposition	Category Item / Characteristic	Source
Task-Technology Fit Quality – right data and level of detail Locatability Assistance Authorisation / access to data Ease of use / training System reliability Accuracy Compatibility Currency Presentation	Characteristics of information systems / services will affect user evaluation	Efficacy Different types of computer systems Availability of assistance	Goodhue (1995) Goodhue & Thompson (1995)
	Task characteristics will affect user evaluation	Level of difficulty non-routine and interdependent tasks Reliability of systems	
	Individual skills and ability will affect user evaluation	Computer literacy Demanding tasks	
	The interaction between task and technology (and individual) will affect user evaluation	Interdependent tasks and information systems Ability and information systems	

Table 2-6: Category of Task, Technology and Individual Characteristics in the TTF

In group task evaluation, group task is defined as "the behavior requirements for accomplishing stated goals, via some process, using given information" (Zigurs & Buckland, 1998, p. 316). An additional factor in group task is the focus on common goals. There will be misalignment of objectives if individuals in the group start to perform the task on a different or personal agenda. The result would be inefficiency in the performance of the task or even incompleteness. To mitigate the different levels of complexity of tasks, Zigurs and Buckland (1998) propose using three functions of group support systems (GSS) for the different tasks:

communication support, processing structuring, and information processing. Communication support is one of the various modes of communicating among members of a group such as simultaneous input and anonymous feedback. Processing structuring is the facilitation in decision making such as agenda setting. Information processing is the various forms of manipulating data. The experiment shows that the use of technology (GSS) supports the different tasks when its characteristics fit that of the tasks (Zigurs, Buckland, Connolly, & Wilson, 1999).

2.5.4 Diffusion of Innovation Model

The recent body of work of the diffusion of innovation has been in the adoption and assimilation of a particular technology, such as: EDI (Chau & Hui, 2001; Ramamurthy, Premkumar, & Crum, 1999); Material Requirements Planning (MRP) (Cooper & Zmud, 1990); and Personal Work Stations (Moore & Benbasat, 1991). The research attempts to find factors or characteristics of innovations and organisations that are favourable for technologies adoption. A more widely referenced and tested work is Rogers' (1995) diffusion of innovation theory.

This section discusses the recent work in innovation diffusion by organisations with particular focus on the primary adoption, that is, the initial adoption stage as discussed previously. Rogers' (1995) five-stage organisational innovation adoption process is reviewed next followed by the discussion of key innovation and organisation characteristics.

2.5.4.1 Five-Stage Innovation Process in Organisations

Rogers' (1995) five-stage innovation process consists of two main phases. In stage 1 and 2, organisations are involved in data gathering to conceptualise and process information for the planning of technology adoption. This is the initiation phase of the innovation process. In stages 3 to 5, the implementation phase, the decision to adopt a technology is underway, putting the technology to use. Several events happen in these stages as organisations craft the implementation process. Figure 2-11 shows the five-stage organisational innovation adoption process.

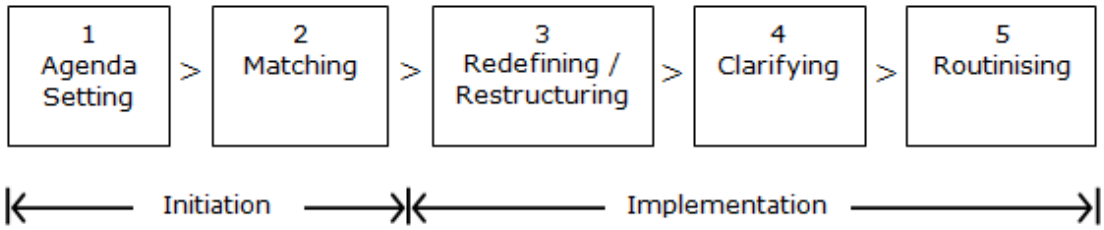


Figure 2-11: Five-Stage Innovation Adoption Process in Organisations (Adapted from Rogers 1995)

The aim of this research is to understand how organisations decide to adopt a technology. Thus the initiation phase is of particular interest here. As previously justified, it is also essential to explore the implementation phase since RFID is a cross-organisational technology.

In the agenda setting stage, organisations are involved in the gathering of information about problems, needs, and solutions. A key characteristic in this stage is the prioritisation of needs and problems. There are often several problems that an organisation faces but with little

knowledge of the possible solutions. Therefore, prioritising the problems is a logical step in dealing with issues under constraints and uncertainty. Another key characteristic is how organisations identify an appropriate technology. In most cases, the awareness of the technology as a potential solution, rather than the needs to solve a problem, is the main driver for organisations to further explore the technology. Rogers (1995) notes that sometimes it is the knowledge of an innovation that trigger the innovation adoption process which results in a perceived need for the technology even though there may not have a problem in the organisations. At this point, a question to ask is whether the need has increased the search process for more information (Zaltman, et al., 1973). Once there is a need identified for the technology, the matching stage starts. Organisations attempt to match the technology to their problems. According to Rogers (1995), this process is planned and designed. It is a crucial stage in the adoption process where the decision to adopt or not to adopt is formed. While it is not explicit at what stage the TTF evaluation of technology occurred, most of the research in TTF was conducted after the technology had been implemented. A reason could be that the research is at the individual level and the decision to adopt the technology has already been taken at the organisational level. Individual members at the organisational level, who are charged with the adoption decision making, start to formally evaluate the technology at the matching stage. They evaluate the fitness of the technology to the organisations values and processes. According to Zaltman et al. (1973), individual members of the organisation by this stage would have already formed certain attitudes towards the technology. Two main attitudes were highlighted. First is openness to the innovation, second is the perception of the benefits of the innovation. That is, are the individual members willing to consider the technology and what are their perceived benefits for the innovation? Since most innovations are discovered prior to a problem (Rogers, 1995), the matching stage becomes a milestone in technology adoption. It is important that at this stage there is sufficient information about the technology

and the organisation for the decision to adopt the technology to take place. It can be argued that organisations may already have formed a preconception of the technology at the agenda setting stage. Since the agenda setting stage could take up to several years (Rogers, 1995), organisations would be gathering sufficient information about the technology during this period. In such case, have the organisations taken too long to make the decision? The missing link between the agenda setting and matching stages is the focus in this research.

During the implementation phase, organisations begin work on transforming the innovations to accommodate their needs and requirements (Rogers, 1995). The stages involve redefining existing processes and to some degree restructuring of organisations. In the case of disruptive technologies, a radical change to the organisation may happen. The management of the organisation change is thus important in this stage. Zaltman et al. (1973) suggest two sub-stages in the implementation phase. In the first sub-stage, organisations conduct trials to determine the practicality of the technology. If the trials are successful with few significant problems, implementation is more likely to continue in the second sub-stage. When this happens, the technology is in place and organisations move on to the clarification and routinising stages. In these stages of implementation, organisations facilitate the use of the technology while attempting to stabilise the processes. Discontinuance of technology can still occur at these stages (Rogers, 1995).

2.5.4.2 Innovation and Organisation Characteristics

Five characteristics of innovations have been proposed by Rogers (1995). They are Relative Advantage, Compatibility, Complexity, Trialability, and Observability. Relative advantage and Compatibility are two commonly used factors in the diffusion body of work and probably

the more influential predictors of adoption (Rogers, 1995). Relative advantage is positively related to the rate of adoption. It is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 1995, p. 229). As organisations may not have the necessary experience with the technology, information about the technology is one of the key references for its Relative Advantage. Incentives in mandated situation can reform or alter the Relative Advantage to favour adoption. Rogers (1995) provides evidence of how higher level of social organisations, such as the government, play their part in influencing adoption, pointing to the family planning policies in China and Singapore as examples. An artificial Relative Advantage, such as incentives, can change the perceived benefits of an innovation.

Rogers (1995) describes Compatibility as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (p. 240). Here, Compatibility is referred to as fitness to organisational beliefs and interaction with external organisations. Organisations work within their values and beliefs and are constrained by them (Christensen, et al., 2004). Technology must be aligned and compatible with organisational practices and policies (Singh, Lai, & Cheng, 2007). Incompatibility with organisational values and beliefs can be a barrier to technology adoption. Besides cultural values, organisations relate Compatibility to past experiences. It could be disastrous if, without prior knowledge of a technology, an organisation uses past experiences to evaluate, or worse, to execute the technology. Rogers (1995) illustrates this issue using the example of how farmers sprayed their potatoes with insecticides as they did with water – the farmers' past experience of spraying water on their crops. Thus experience could work against Compatibility if there is insufficient information. Compatibility with needs is another important aspect in the evaluation of technology. Be it introducing integrated systems to supply chain partners or convincing top management about the benefits of an innovation,

realising the needs for a particular technology requires more than just assessing the benefits. It requires the understanding of the technology, organisations, and external environmental aspects of using or adopting an innovation. The other three characteristics, complexity, trialability, and observability are self-explanatory. All three refer to usage and results of using an innovation. Complexity is the level of difficulty. Trialability is the degree of experimentation possible with the technology. Observability is the visibility of the outcomes as a result of using the technology.

While the DOI looks at the adoption of technology as a process, it is not clear how it can be applied to external factors, such as, the environmental impact and supply chain partners' influence in technology adoption. The next sections introduce two frameworks that cover the external aspects of supply chains.

2.5.5 The Motivation/Ability Framework

The MAF is based on Christensen et al. (2004) definition of the elements required for innovation in an organisation. "The motivation/ability framework suggests that innovation flourishes when companies have both the motivation and ability to innovate. Market contexts that are deficient in motivation or restrict ability are stifling to innovation" (Christensen, et al., 2004, p. 21). There are two factors entailed in the MAF. Motivation is defined as market incentives to implement with the innovation. Return on investment or profitability is one such motivation in the corporate world. Other motivations are cost savings and gaining market share through the use of innovations. Ability is defined as the capability to turn available input into meaningful output where there is real demand.

The framework suggests that non-market forces affect the motivation and ability to innovate. Industry standards, unions, technological development, and government policies are such potential forces and these are particularly imperative in the adoption of RFID/SC. Frankel (1990) also suggests that work rules and government regulations constrain the effective use of innovation. This section explains three principles of the MAF in an attempt to create an awareness of the effects of government intervention.

The traditional view of government intervention was that it would lead to less innovation. Intervention was deemed to restrict companies to certain options, thus limiting innovation. However, in recent innovative initiatives, institutions like government agencies, academia, and market leaders are entering the innovation cycle at a much earlier time (Frankel, 1990). The United States Department of Defence, Auto-ID Centre, GS1, Wal-Mart, Target, and Metro are some examples. Christensen et al. (2004) argue that government involvement has successfully supported the development of innovative technologies, pointing to the Internet and healthcare as examples. The Internet project was largely funded by government agencies, and support groups were also set up by the government to modernise healthcare systems in the United States.

Four industry categories depicted in the MAF are illustrated in Figure 2-12: the hotbed; looking for a target; looking for the money; and the dilemma.

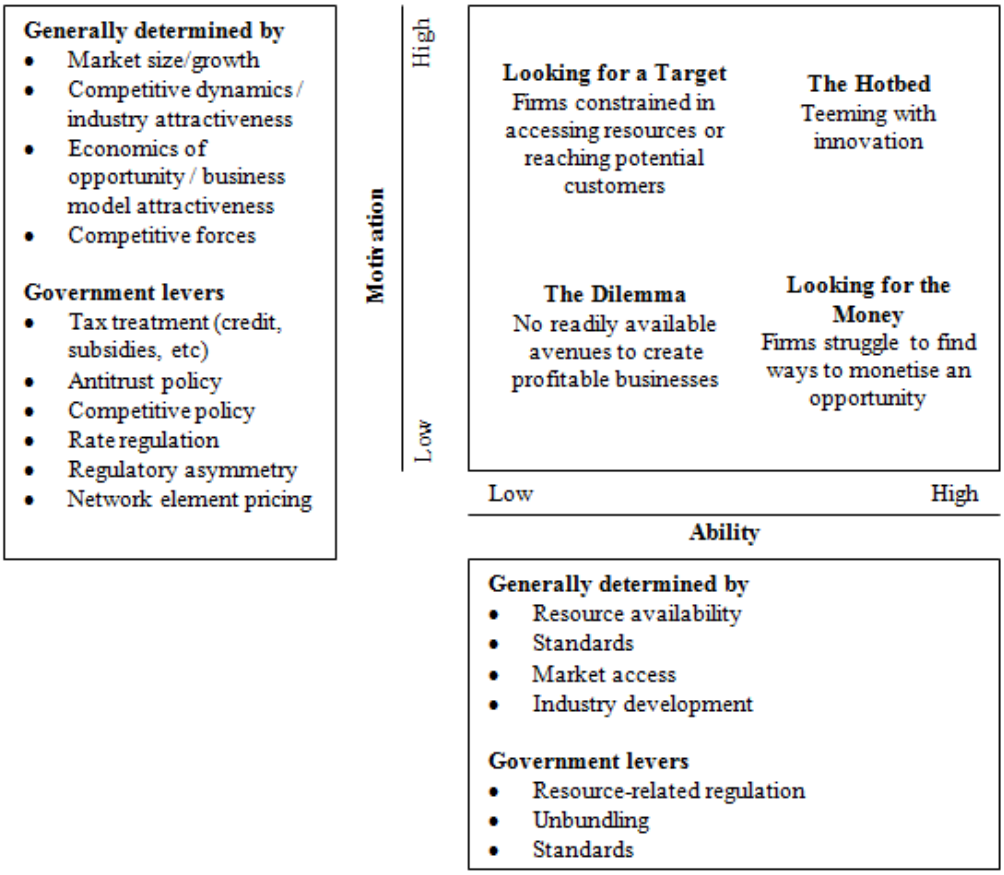


Figure 2-12: The Motivation/Ability Framework (Christensen 2004)

Hotbed

The hotbed category has an abundance of both motivation and ability. There are opportunities for everyone in this market. In this situation, incumbents continue with the aim of sustaining technologies, while new entrants develop new innovation for disruption. The hard disk industry was one such hotbed (Christensen, et al., 2004).

Looking for a target

The looking for a target category is where companies see the benefits of the investment but lack the ability to innovate. The framework suggests industry standards, availability of

resources, access to markets, and the development of industry as possible hindrances to innovation. Non-market forces such as government and institutions play vital roles in regulating these deterrents. The unbundling of telecommunication networks is one such policy to liberate existing infrastructure for competition. For example, this allows other industries, such as the cable company, to provide innovative services to consumers (Christensen, et al., 2004). In RFID/SC, retailers are likely to be in the 'looking for a target' category based on evidence provided in previous chapters. They realise the benefits of RFID/SC but lack the ability to capitalise on the invention without having to depend on their suppliers.

Looking for the money

The looking for the money category is the direct opposite of the looking for the target category. In this category, companies have the ability to create innovative services and products for the consumer. However, they are unable to find profitable returns in the initial stage of the development. The framework suggests the size of the market, level of competition, and attractiveness of the industry as possible factors used to determine the profitability of the innovation. Frankel (1990) suggests that the size and composition of the industry, and the degree of competition, affect the rate and timing of technology diffusion. The top suppliers in the RFID/SC mandate situation certainly fall into this category to begin with. They might have the resources to adopt RFID/SC but lack foreseeable benefits from this innovation (Roberti, 2004c).

Dilemma

The rest of the majority would fall in the dilemma category, the fourth and last category in the MAF. In the dilemma category, there is a lack in both the motivation and the ability to adopt

innovation. Christensen et al. (2004) predict that it is difficult to create innovation in this category.

The MAF allows one to make sense of an industry by mapping players in the industry into the four categories. One will then be able to have some idea of the strategies to use and pit-falls to avoid. Christensen et al. (2004) suggest three principles when evaluating policies that intervene in a market's innovation.

2.5.5.1 Creating the right kind of motivation is hard

There are many factors driving a market imbalance. The interpretation of these factors by policymakers might be influenced by the wrong signals resulting in only temporary motivation. Incentives injected by the government may lead companies to create unsustainable business models (Christensen, et al., 2004). This is because it may take longer than expected to realise the returns on an investment as the market is unpredictable. Christensen et al. (2004) argue that only the government is capable of coping with competitive dynamics in the long run. Investors are usually less patient in terms of sustaining a business, particularly when they are financially stretched and under pressure to deliver results.

In RFID/SC, suppliers without sufficient budget to support the initial set up might not be able to invest in the additional investment required to implement RFID in a mandate.

2.5.5.2 Legal ability does not always create technological or operational ability

Government can be very successful in lifting legal barriers. Providing new entrants with incentives and forcing incumbents to unbundle are examples of government intervention. However, when technologies are the barriers, Christensen et al. (2004) argue that governments would be less successful. Therefore they caution that even when legal barriers are lifted, one has to be aware of other technological or operational barriers. Christensen et al. (2004) provide case studies of the Telecommunication Act in the United States as examples of how government policies that attempt to create competition by deregulating the telecommunication market may not be as successful as expected. Although new entrants had been given the motivation to participate in the telecommunication market, because of their interdependency on the incumbent legacy infrastructure, they struggled to keep up with the competition.

In RFID/SC, a similar situation may arise due to multiple systems used in a supply chain, some of which are proprietary. The systems could be vendor managed inventory system, customer enterprise resource planning system, and freight management systems, to name a few.

2.5.5.3 Getting out of the dilemma is hard and takes time[6]

Emerging technologies are largely unknown, unproven and the market does not yet exist. It was learnt earlier that the market that does not exist cannot be analysed. Thus, to further develop the technology, it requires substantial investment and involves high risks. Only

[6] This refers to the dilemma category where motivation and ability are lacking.

government and financially sound institutions are capable of filling this role. This is because the long term yield is just not attractive to fast growing companies. The government, in particular, has the capacity and interest to invest in cultivating a more competitive market for businesses. However, in an existing market, such intervention may likely jeopardise the market forces in action. Christensen et al. (2004) believe that trying to encourage both motivation and ability simultaneously almost always fails. They argue that government policies work better in providing the ability for the industries to innovate, while they are not as successful in motivating them. As such Christensen et al. (2004) suggest concentrating on creating ability for new entrants to enter the market and leaving them to find their own motivation. This approach allows companies to innovate and find their own business cases. Those companies that are not motivated will exit from the market or find a new market, while those motivated will continue to venture in the market as they develop the ability to sustain the business.

The Christensen et al.(2004) warn that motivation as a result of wrong interpretation of the market could be disastrous. Understanding a market condition does not guarantee success. One has to understand its own ability in terms of operational and technological capabilities. Governments and large organisations have the ability to influence a market condition but to a limited extent. Success still relies upon the organisation's ability to innovate and create its own motivation to continue the business.

There are two examples of Governments' support of RFID in terms of lifting operational and technological barriers:

a) In Asia and Europe, the Governments are investing heavily in operationalising the use of RFID in supply chains. The intervention lifts the barriers to RFID implementation and thus provides motivation for organisations to innovate. The European Commission (EC), in particular, is anxiously funding RFID projects in the fear of falling behind the global trend of adopting RFID/SC (Edwards, 2008a; Sayer & Hanover, 2006).

b) In their effort to lift the technological barriers to RFID implementation, the EC is involved actively in ratifying standards and policies on the use of radio frequency as well as privacy concerns (Wessel, 2007a). The move attempts to harmonise standards in Europe and thus speed up the adoption of RFID.

Both cases illustrate the intervention of government in lifting barriers to technology adoption. This may prove successful in aligning standards across countries and regions. However, organisations are to craft their own strategies in dealing with the other aspects of the disruptive technologies as mentioned in the earlier sections.

In RFID/SC, various governments are taking steps to enable the use of radio frequency for RFID/SC by allocating frequency bands to the application of RFID. Institutions, such as the Auto-ID Centre, have developed roadmaps for the implementation of RFID and EPC in the supply chain. GS1 is taking on a larger role providing a platform for harmonising the various trade standards. The users of RFID/SC have to find their own motivation, with all those abilities set up for them, in order to have a higher chance of succeeding in RFID/SC. Table 2-7 shows where RFID/SC is relevant to the principles.

Frameworks	Key Principles	Findings	RFID/SC Context	Recommendations
Motivation/ Ability Framework **(non-market forces)**	Creating the right kind of motivation is hard	Wrong interpretation of market forces might result in temporary motivation that portrays false return on investment.	Suppliers without substantial budget might not be able to sustain the investment.	Companies to find their own motivation that is in their vested interest.
	Legal ability does not always create technological or operational ability	Governments would be less successful in removing technological barriers.	Drawing lessons from telecommunications deregulation, new entrants to RFID/SC might struggle to integrate with incumbent legacy infrastructure due to complex interdependency.	Assess all possible technological and operational barriers.
	Getting out of the dilemma is hard and takes time	When both motivation and ability are lacking, it requires substantial investment and higher risks to cultivate a market. Only governments and financially sound institutions are capable of filling this role.	In the RFID/SC context, the Auto-ID Centre developed feasible roadmaps for the implementation of RFID and EPC in the supply chain, while now GS1 is taking on a larger role of providing a platform towards harmonizing the various trade standards.	Government policies should work on providing ability for new entrants to enter the market and leave them to find their own motivation. Support industry-led RFID initiatives.

Table 2-7: RFID/SC and the Motivation/Ability Framework

2.5.6 Technology-Organisation-Environment Framework

The TOE framework is commonly used by diffusion authors although they might not share the same terms (Chengalur-Smith & Duchessi, 1999; Iacovou, Benbasat, & Dexter, 1995; Orlikowski, 1993; Tornatzky & Fleischer, 1990; Zhu, Kraemer, & Xu, 2006). Tornatzky and Fleischer (1990) describe three contexts in which innovation assimilation can take place: technology, organisation, and environment. Technology context refers to existing and new technologies which may involve systems integration. Organisational context refers to the organisation's attributes such as scope, size, values, processes and management. For example, decentralised organisations are more likely to initiate innovation adoption and at a faster rate

(Daugherty, Germain, & Dröge, 1995; Moch & Morse, 1977; Zaltman, et al., 1973). Environment context refers to the marketplace where the organisation operates including other players. Players may include government and the community. The common environmental factors are competitors and foreign policies or regulatory issues (Zaltman, et al., 1973). Market competitiveness and organisation position in the market influence technology adoption rates (Chengalur-Smith & Duchessi, 1999). Table 2-8 shows the items for each of the contexts.

The adoption of a TOE framework by these diffusion scholars was to describe contextual characteristics that were perceived to influence technology innovation in some ways. Specific factors within the three contexts were adopted to describe the intention to adopt and use a technology.

Model	Variable	Category Item	Source
Technology – Organisation – Environment Framework	Technology	Compatibility Readiness Integration Technology fit Relative advantage	Chengalur-Smith & Duchessi (1999) Iacovou et al. (1995) Orlikowski (1993) Zhu et al. (2006)
	Organisation	Organisation size Global scope Managerial obstacles Organisation strategies Readiness Compatibility Complexity of organisation	
	Environment	Competition intensity Regulatory environment Support / Facilitation Pressure	

Table 2-8: Category of Items in the TOE Framework

2.5.7 Comparing the Models: Why there is no one size fits all

After reviewing the various adoption models, this section analyses the merits and limitations of the models discussed. The purpose is to draw on the strengths of each model to form the epistemology for research in technology adoption and propose a new conceptual model that leverages the strengths of the existing models and overcomes the weaknesses of the existing models.

In the literature, the discussed models are often classified as individual or organisational levels adoption models. The TAM, TPB, and TTF are usually classified as the individual models. These models are used in the study of technology acceptance by individuals, although sometimes by groups, and suited for standalone systems such as personal computer, World Wide Web, mobile phones, and more. The DOI, MAF, and TOE models are classified as organisational level models where social indicators are more highly relevant. Scholars using these models adopted a process approach to study the adoption, implementation, and assimilation of technology. An example of a process approach is the Five-Stage Innovation Process in Organisations (Rogers, 1995). Examples of technologies explained by the organisational models are the adoption of EDI, computer-aided software engineering, client-server systems, e-business, and more. Figure 2-13 shows the characteristics of the models and their position in relations to technology and organisation contexts. The models are grouped into three clusters based on their characteristics in relation to both the contexts.

The organisation characteristics axis represents the units of analysis that the models are deemed to fit best based on literature. The technology characteristics axis represents a set of social factors that either have lower or higher social influence on technology innovation. For example, in a case where users have the power to use, or not to use, a technology, it is usually

a knowledge tool designed for individual consumption and thus volitional. "Personal considerations tended to overshadow the influence of perceived social pressure" in such cases (Ajzen, 1991, p. 189). Technology with higher social influence is usually a group system and, in certain situations, a mandate is issued or pressure exerted for its adoption, such as, EDI adoption in the Government sector (Iacovou, et al., 1995).

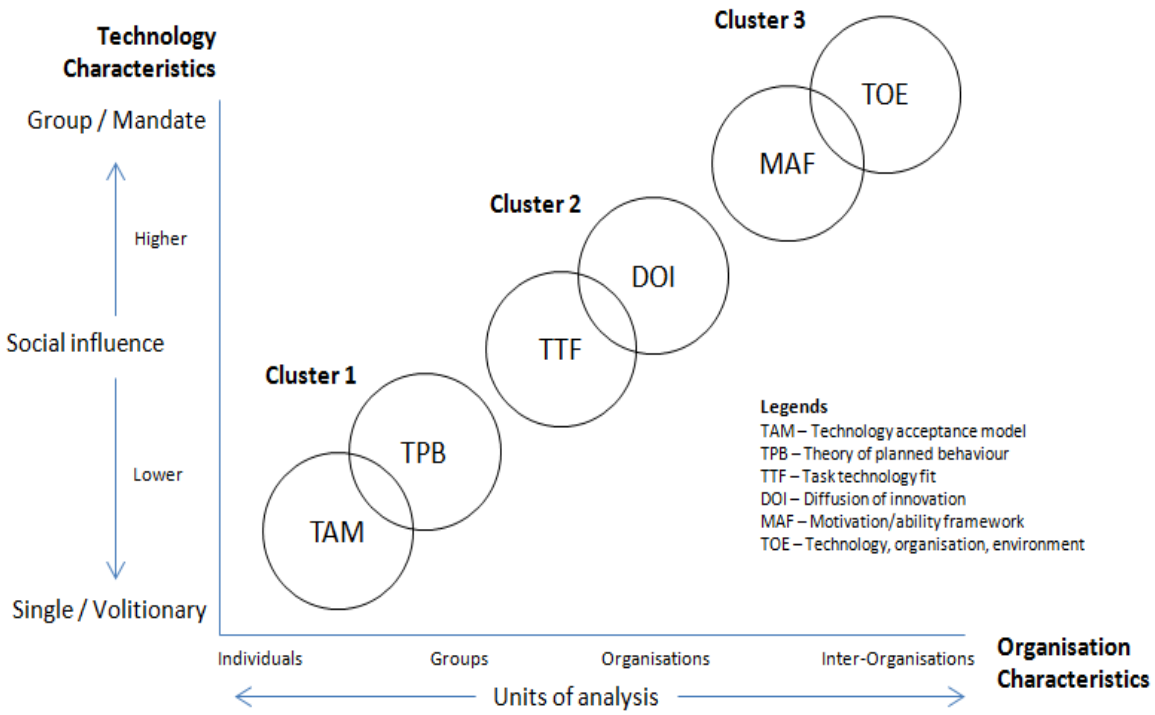


Figure 2-13: Comparing the Models

What is not shown in Figure 2-13 is the environment context. It is assumed that in a highly social context, such as a group technology that involves inter-organisational units, the external environment needs to be considered when evaluating the adoption behaviours of the units. Cluster 3 has the environment characteristics in the frameworks whereas cluster 1 has no clear environmental measures. The TAM and TPB are placed in the lower scales of both contexts, in cluster 1, as they are designed for individuals to groups technology acceptance study. The

Behavioural Control in TPB captures social influence in which TAM is lacking. Thus TPB is placed slighter above TAM in Figure 2-13. TAM has been widely tested and found to be a power attitudes prediction model in individual and volitionary technology adoption situations. Its perceived usefulness has been constantly found significant by researchers. However, its perceived ease of use may not be a strong predictor of user's intention over a period of time. TPB has developed to include the measure of uncertainties around the ability of individuals to achieve an intended behaviour. The inclusion of Behaviour Control in TPB brings in the consideration of the availability of resources and opportunities. It measures the perception not only of ease, but also the difficulty in achieving a behaviour. Thus, TPB overcomes the weakness of perceived ease of use in situations where resources and opportunities are important. Nevertheless, both TAM and TPB are too simplistic in their prediction of behaviour. In reality, there are additional constraints such as time, dependency on trading partners, and cooperation with others (Mathieson, 1991). Neither TAM nor TPB have explicit measures for such external factors.

TTF and DOI form the cluster 2 as shown in the figure. They are capable of predicting a more complex social influence in higher units of analysis than TAM and TPB. TTF measures the self-evaluation of users in terms of how the technology assists in completing their tasks. It has a certain degree of external factors such as interdependent of tasks and reliability of systems. DOI literature looks at the adoption of technology as a process and identifies five factors that are predictors of adoption. The five factors are found to be relevant to organisational technology adoption by researchers (Christensen, et al., 2004; Singh, et al., 2007). Rogers (1995) describes the five factors in the organisational and technological aspects. For example, he suggests the need to consider Compatibility with organisational values and the integration of systems. However, it was not clear that the measurement of the five factors should be

applied to the external environment although in some of his examples, Rogers (1995) refers to external factors such as climate in agricultural innovation. Thus, both TTF and DOI may not include consideration of the external forces (environmental aspects), which is important in technology adoption at supply chain level.

The third cluster is the MAF and TOE frameworks. They cover external forces, such as the environment in which an organisation operates. It is therefore capable of capturing a wider social influence in an inter-organisational context. MAF provides the evaluation of the motivation and ability of an organisation in adopting a technology. It describes the marketplace in which an organisation operates. However, it does not measure the internal factors that affect technology adoption that previous models measure. TOE in contrast has clear delineation of the three aspects of an organisation: technological, organisational, and environmental. TOE spells out specific factors for each of the three aspects. For example, integration is a factor in the technological aspect and pressure is a factor in the environmental aspect. Only Compatibility and Readiness are evaluated across the technological and organisational aspects. Thus, as MAF and TOE have the environmental aspects of technology adoption, they do not offer a end-to-end evaluation of a factor which is important if the technology adoption is to impact on a wider context of an organisation. Rogers (1995) suggests that evaluating the context in which the technology adoption is taking place is important in a “new wine but it is poured into old bottles” situation. Technology adoption at the supply chain level requests the focus upon network technology innovation diffusion” (Wamba & Chatfield, 2009, p. 617). Thus, it is important to consider a factor across the three aspects of TOE to achieve a network focus at the supply chain level.

A linear pattern can be easily spotted in Figure 2-13. This seems to suggest that as the units of analysis increases in size, the influence of social pressure increases as well. It should be warned that the figure does not suggest a certain linear coefficient between the two contexts but it merely shows a general trend towards the outer continuum of the contexts considered. The figure also shows there is no one size fits all model. The critiques above suggest that a new model that considers key innovation characteristics across technological, organisational, and environmental aspects of an organisation is needed for a network technology adoption in a supply chain.

The next section looks at what other researchers have done in terms of RFID adoption in supply chains.

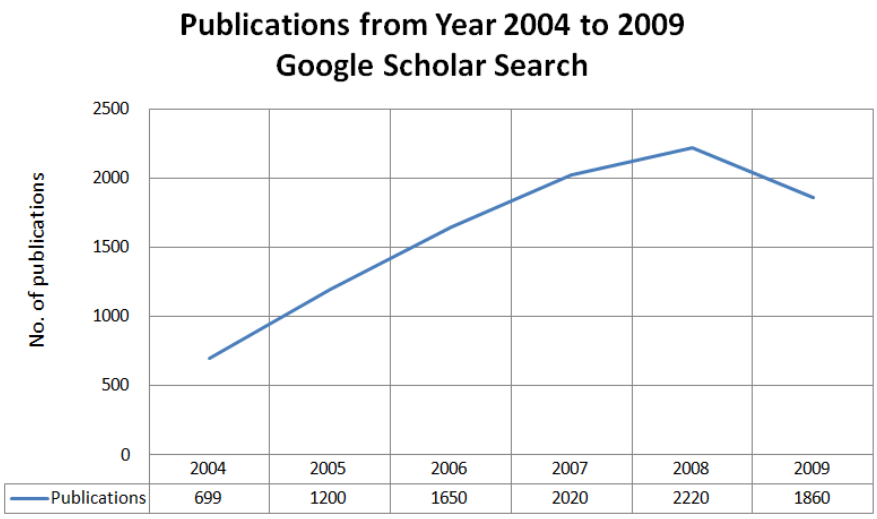
2.6 RFID Adoption in Supply Chain Studies

Research in RFID has grown in recent years with an increasing number of journals calling for papers on RFID-related topics, or including RFID as a topic. More literature on RFID/SC was published from 2007 to 2009 than previously. Two sets of search were carried out; one using Google Scholar Search and the other using ABI/INFORM for comparison. The Google Scholar Search elicited 6100 articles on RFID in supply chain published from 2007 to 2009 and 3549 from 2004 to 2006. The ABI/INFORM search returned with 99 articles from 2007 to 2009, and 45 articles from 2004 to 2006. Both sets of search showed similar increment trend in the number of articles published in the same period. Figure 2-14 show the increase in RFID/SC publications from 2004 to 2009 as elicited by the two databases.

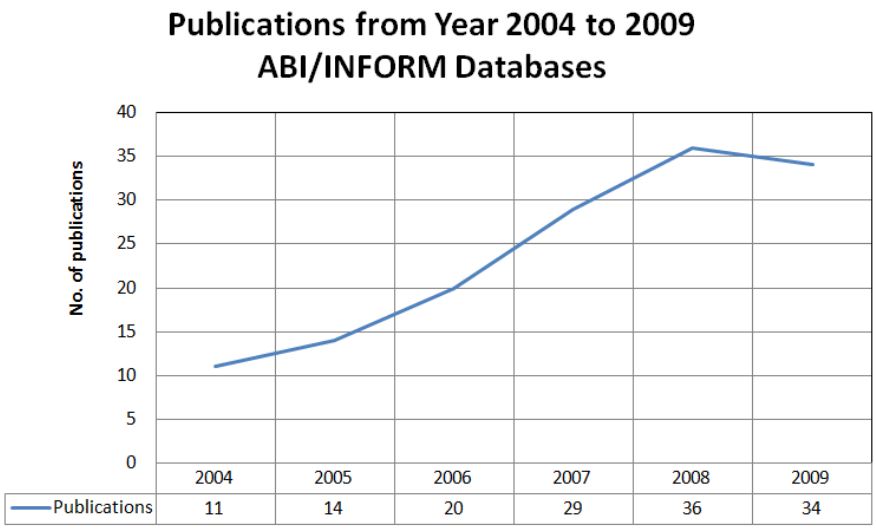
Before the start of this research in 2006, most RFID research is focused on the technical aspects of RFID. Three years on, technical papers and papers about the technical aspects of RFID are still dominating the research in the field. Appendix A shows some of the publications from 2007 to 2009 from a single database.

The next popular research focus is the benefits and issues of RFID in supply chains. Topics discussed are generally the impacts of RFID in specific areas, such as in the Fast Moving Consumer Goods (FMCG) industry (Bottani & Rizzi, 2008; Miragliotta, Perego, & Tumino, 2009), inventory control (Heese, 2007; Szmerekovsky & Zhang, 2008), in specific industries, such as textiles (Kwok & Wu, 2009), pharmaceuticals (Matalka, Visich, & Li, 2009), and in specific countries such as Sweden (Johansson & Pålsson, 2009), China (Luo, Yen, Tan, & Ni, 2008), and Taiwan (Shih, Chiu, Chang, & Yen, 2008). Research in the implementation of RFID is the next common research focus followed by adoption.

In terms of research methods, while conceptual and analytical approach is common, field research using case studies is also widely adopted among these publications. Most of the case study research is focused on a single unit (Martínez-Sala, et al., 2009; Tewary, et al., 2009) and few are focused on multiple units (Moon & Ngai, 2008; Wamba & Chatfield, 2009). Implementation dominates as the research topic in the pool of case study research.



The search criteria are: "RFID" and "Supply Chain" as the key words, specific date ranges (2004 to 2009); non-citation and articles excluding patents are selected. Search database: Google Scholar.



The search criteria are: "RFID" and "Supply Chain" as the key words, specific date ranges (2004 to 2009) and only scholarly journals including peer reviewed from the ABI/INFORM (global) database.

Figure 2-14: Scholarly Publications on RFID in Supply Chain

While there are many articles on RFID adoption in supply chains, few of them are focused on the factors affecting the adoption of RFID in supply chains. Ten publications are selected as reference point for this research based on their scholarly work and contribution to the technology adoption field. They are selected such that a balance of intra and inter-

organisational RFID/SC technology adoption are represented. They are published in recognised journals or conferences, and are representatives of research in RFID/SC adoption. Eight of the ten publications used survey as the main research method, the other one used case study, and another one used theory based methods. Table 2-9 shows the ten publications on RFID adoption in supply chains ordered by the research methods and authors. Factors found significant or important by these authors are depicted in the table. The findings, categorised into familiar themes, and key note are also shown in the table.

The findings in the publications in Table 2-9 are categorised into themes based on other theoretical work on technology adoption. Common themes can be easily identified from the table. Among them are Top Management Support, Environment, Industry Standards, Organisational Size, Facilitation, Compatibility, Motivation and Government Support.

Top management support is found important in Lin and Ho (2009), and Wamba and Chatfield (2009) but with different descriptions. Koo, et al. (2007) suggest successful adoption of technology depends largely on “leadership, support, and coordination of manager … [to] cope with risks of failure caused by the lack of financial support” (p. 186). Wamba and Chatfield (2009) refer to Top Management having a role in mitigating the impact of environment uncertainty positively to organisational learning through effective leadership. Lin and Ho (2009) found that resource support and leaders’ attitudes toward innovation as an organisational culture had influence in RFID technology adoption. The involvements of senior management in the process of technology adoption is thus to facilitate in various aspects of organisational technology innovation.

Research	Code	Method	Important Factor	Theme	Key Note
Cannon, Reyes, Frazier, & Prater, 2008	A	Theory based	Uncertainty across contexts and levels Embeddness of IS Lack of widely used RFID standards	Traceability (information) IT integration RFID standards	RFID adoption decreases material flows uncertainty but increases information processing
Wamba & Chatfield, 2009	B	Case Study	Leadership Environment	Top management support Organisational readiness	Environment upheaval has positive & negative impacts
Bendoly, Citurs, & Konsynski, 2007	C	Survey	Information-processing standardisation Expertise in technology Procedural flexibility	Information Ease of implementation Trialability	Reliable IT infrastructure is critical to RFID initiatives
Chang, Hung, Yen, & Chen, 2008	D	Survey	Environmental uncertainty RFID provider's environment Pressure from partners and competitions High implementation costs Integration supply chain strategy Mutual standards	External environment Facilitation Pressure Organisational strategy Complexity Industry standards	Government to establish standards and regulations to reduce complexity and uncertainty
Koo, Lee, Shao, Koh, & Jo, 2007	E	Survey	Environmental uncertainty Top management support Organisational size IT infrastructure Tag compatibility	Organisational size Top management support External environment Compatibility	Trust and power are important moderators
Lin & Ho, 2009	F	Survey	Explicitness of technology Accumulation of technology Organisational encouragement for innovation Quality of human resources Governmental support	Relative advantage Top management support Government support Facilitation Self-efficacy	Environment uncertainty not significant in China Government support can encourage adoption
Lin, 2009	G	Survey	Willingness of supply chain members System compatibility Readability Strong leadership System integration Government support	Internal & external environment Compatibility Industry standards Facilitation	Government or industry associations support is critical for a successful adoption
Pedroso, Zwicker, & Souza, 2009	H	Survey	Motivated companies seek and implement potential application Motivations led to consequent search for information	Motivations Organisation preparedness	Company size is not significant Difficulties not determinants in adoption
Shih, et al., 2008	I	Survey	Operational efficiency Supply chain efficiency Market environment uncertainty High cost of tags Concerns over standards	Perceived benefits Industry standards Motivations	Cost is not a significant barrier Suggest to wait and see
Whitaker, Mithas, & Krishna, 2007	J	Survey	Broad IT application deployment Early return on investment	IT infrastructure Industry standards	IT budget and RFID adoption do not have strong relationship

Table 2-9: Category of Research in RFID Adoption in Supply Chain

Environment uncertainty is found in almost all of the ten publications in different perspectives. They can be grouped as industry, trading partners, and technological uncertainties. Industry uncertainty refers to the complexity of marketplace in which an organisation operates in. For example, Chang, et al. (2008) found that the logistics industry in Taiwan was competitive and had imbalance of power among trading partners. They found that uncertainties in the industry environment have influence on RFID technology adoption. In contrast, Lin and Ho (2009) found that was not the case in China. They argued that organisations are used to operate in uncertainty environment in China's logistics industry and the organisations are adaptive to the uncertainty.

Chang, et al. (2008) also found there was uncertainty in the RFID vendors' support given to adopting organisations. This is again linked to the highly competitive marketplace in the logistics industry. RFID vendors have better incentive working with a larger, more powerful organisation in the returns they get when compared to working with a smaller organisation with fewer orders volume. Chang, et al. (2008) state that the maturity of RFID technology "is fully dependent upon the [vendors'] industry environment" (p. 212). While the maturity of technology is an important aspect in technology adoption, Pedroso, et al. (2009) suggest at least to consider "the issues of technology reliability and standardization" (p. 884).

Chang, et al. (2008) pointed out that in an uncertain industry environment, innovation technology should be adopted (Gatignon & Robertson, 1989; Kwon & Zmud, 1987), thus suggesting industry environment uncertainty has a positive influence on technology adoption. Cannon, et al. (2008), and Wamba and Chatfield (2009) suggest further that RFID adoption may increase uncertainty but that excessive environment upheaval has impact on organisational learning. While implementation of RFID can be a strategy in reducing

uncertainty in the industry environment, such as to qualify a supplier in a supplier scarcity environment by deploying RFID to overcome the uncertainty, it may result in changing an organisations' relationships with buyers, suppliers, and even competitors (Cannon, et al., 2008). The ability of an organisation to handle uncertainty is also a factor related to environmental uncertainty. Wamba and Chatfield (2009) postulate that environmental upheaval, such as RFID mandate, has a positive impact on organisational learning about the technology and adoption. However, excessive pressure beyond organisational capabilities has impact on the adoption. They refer to organisational readiness as an antecedent to overcome the uncertainty in the capability to adopt technology.

Koo, et al. (2007) suggest the variety of products and services offered makes the prediction of the market conditions a difficult task. Organisations are dependent on their trading partners' choices of the industry standards for their RFID adoption. With the different standards available, adoption of RFID beyond an organisation's boundary is a challenge. This is a technological uncertainty.

The lack of an agreement on industry standards is found a barrier to the adoption of RFID (Cannon, et al., 2008; Chang, et al., 2008; Lin, 2009; Shih, et al., 2008; Whitaker, et al., 2007). "As RFID standards are developed and agreed, this would change the expectations of firms to receive an earlier return on RFID investment, and should spur further RFID adoption" (Whitaker, et al., 2007, p. 607). Industry standard is a crucial aspect of RFID technology, particularly for global organisations. Each country has specific policy on the use of radio devices and thus the internationalisation of supply chain information system requires standards that are compliant with the policy in which it operates. Chang, et al. (2008), Lin

(2009), and Lin and Ho (2009) suggest that government support is important for such an industry-wide standard, to facilitate RFID adoption in the supply chain.

Besides a need for industry-wide standards, other technical challenges are systems integration and IT infrastructure. They are compatibility issues. Adopters are likely to have a set of technological characteristics or competency. Some of the characteristics discussed in the ten publications are, embeddness of IS (Cannon, et al., 2008), broad IT application deployment (Whitaker, et al., 2007), and supply chain integration strategy (Chang, et al., 2008).

Related to technical competency is skills an organisation has in adoption and implementation of IS. Bendoly, et al. (2007) found that knowledge of RFID has significant positive impact on managers' perceptions of RFID but no evidence of support on adoption. Shih, et al. (2008) in their study found perceived benefits, in efficiency improvement, have influence on RFID adoption. Bendoly, et al. (2007) further elaborate that having existing codified information-processing standards with trading partners, organisations are more likely to have both positive perceptions of RFID and greater commitment to adopt RFID. Existing interorganisational systems (IOS) act as a proof of concept that demonstrate the benefits and relative advantage of information-processing standards. An example is the ERP system (Bendoly, et al., 2007). For organisations without any IOS, the ability to conduct RFID trials as proof of concept may equally be valuable to adoption decision.

The benefits of an IS may motivate the adoption of the technology (Shih, et al., 2008). Pedroso, et al. (2009) suggest that motivated organisations seek more information about the technology leading to more knowledge of the benefits. The motivational/ability framework states that organisations are to find their own motivational factors to successful adopt and use

a specific technology. Unlike the ability factors where government or industry associations can facilitate and support, motivational factors are left to the organisations to define.

Organisational size is also mentioned in some of the ten publications. While most researchers found organisational size a factor that influence technology adoption, Pedroso, et al. (2009) found that it is only significant in "the initial intention of adopting or not, but, once adoption has been decided, smaller companies are not differentiated from the remaining [larger companies] regarding stage[s] of adoption" (p. 894).

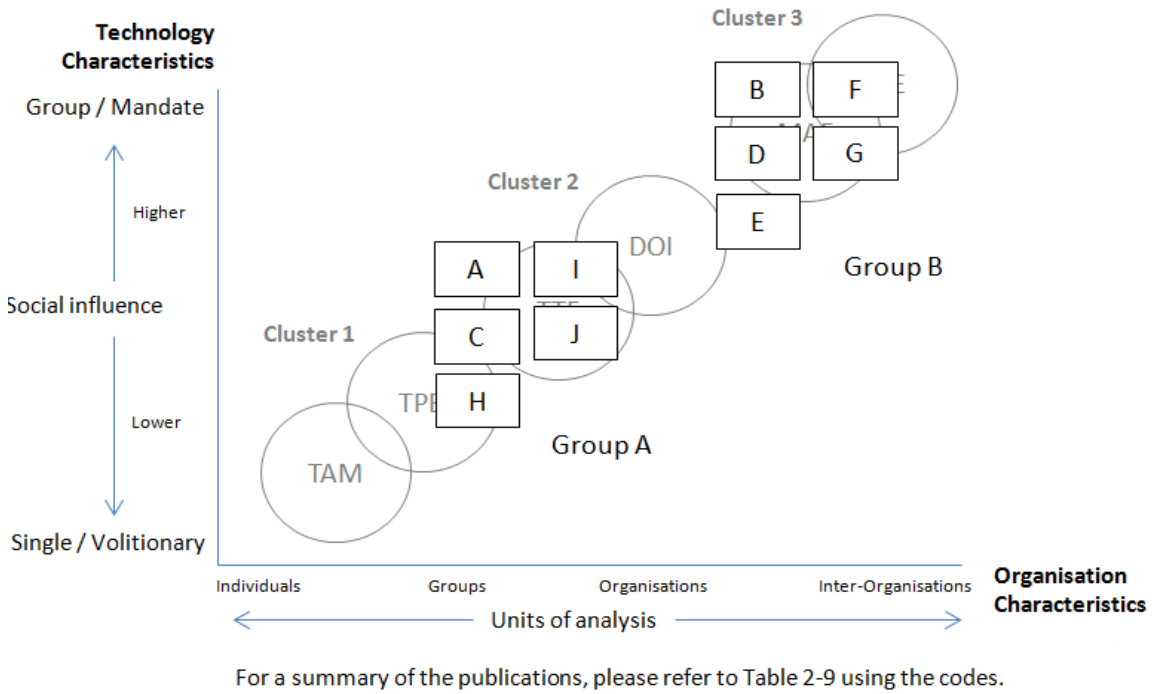


Figure 2-15: Analysis of the Ten Publications

When mapped to the adoption models chart (Figure 2-13), the ten publications seem to fall into two distinct groups as shown in Figure 2-15. Group A is the collection of publications that has a focus in organisation's factors, such as, investment and technical issues. Group B,

in contrast, is the collection of publications that has a focus which includes government intervention and external environment. Therefore, Group B represents publications that have a balance view on an organisation's internal and external factors that might have effects on its RFID/SC adoption challenges. However, the research studies in Group B seem to be limited to inter-organisational challenges, whereas, RFID/SC adoption is a supply chain challenge. Wamba and Chatfield (2009) is probably the only one of the ten publications that has explored RFID/SC adoption in a supply chain manner by interviewing various supply chain members of a third party logistics organisation. Hence, there is a need of a wider study of RFID/SC adoption that compares the challenges faced by different members in a supply chain.

2.7 Problems, Issues, and Requirements

In the above sections, the literature on RFID, supply chain management, RFID in supply chain, technology adoption, and research studies on RFID in supply chain were reviewed. This section discusses the problems and their issues identified from the literature review to set forth the requirements that will be the focus for this research. Figure 2-16 is the synthesis of problems and issues and the figure shows the requirements that may address the identified issues.

2.7.1 Problems and Issues

The unique characteristics of New Zealand businesses do have some issues. First, the distance to market results in high level of damages to goods. Second, the small firm size of the majority of New Zealand companies is an issue of less power in dealing with trading partners and being isolated from key players in the industry. Third, preferential of suppliers and

customers by larger companies due to New Zealand small economies has created the isolations of power. To address the issues, smaller companies may require motivation and facilitation to adopt technology. There is a need for a Relative Advantage of using the technology particularly to overcome the distance barrier. The above issues create uncertainty and fragmentation in the supply and demand of RFID standards and hardware. Thus the lack of agreed industry standards and pressure from trading partners are potential issues to be addressed.

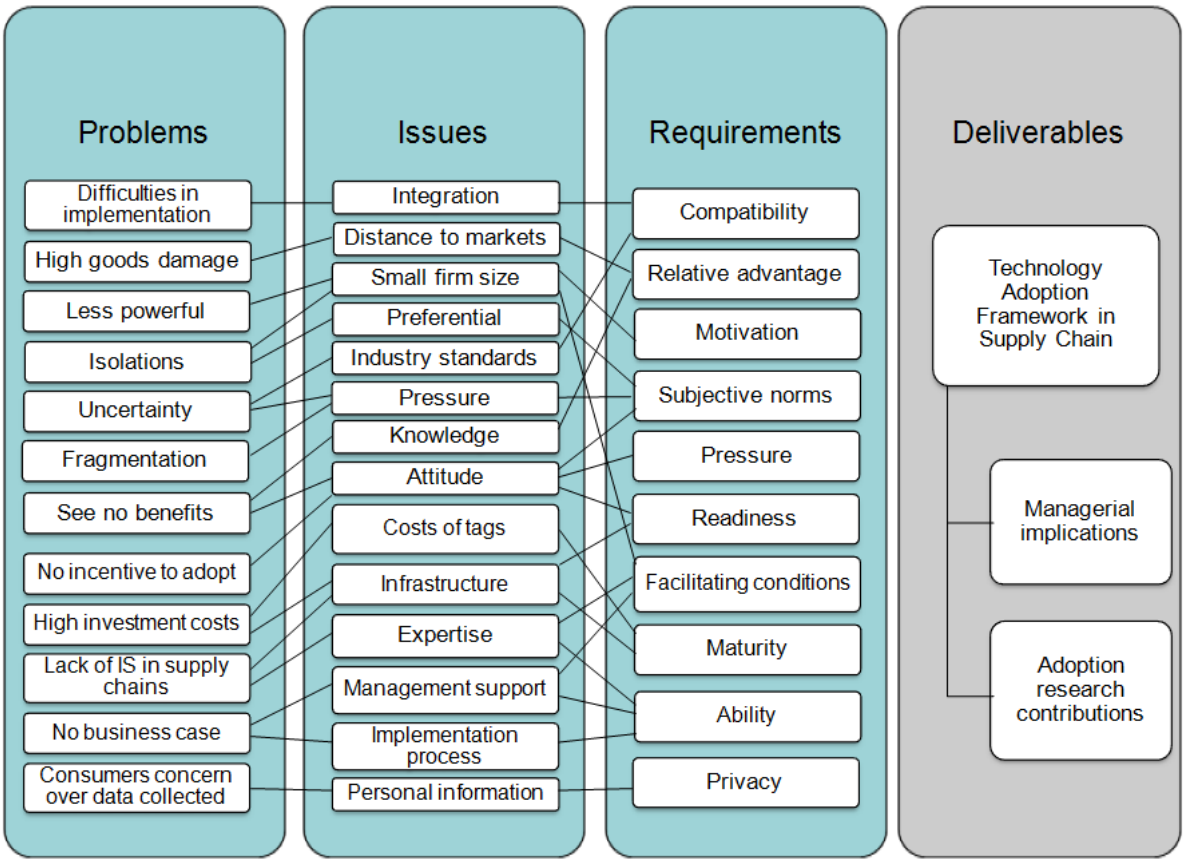


Figure 2-16: Problem, Issues, and Requirements + Deliverables

In the general literature, it is found that companies had no incentive to adopt RFID in their supply chains as they were unable to see the benefits or they have no business case to justify

their RFID investments. These were largely due to the costs of tags and infrastructure of RFID systems. Knowledge of the technology may be the other issue. Companies were unable to see the benefits of RFID because of the lack of knowledge of where and how RFID can yield benefits for them. Thus, the attitude of wait and see could be an issue that needs to be addressed. The attitude could be overcome with Readiness of the companies and the Maturity of the technology, assuming that costs would drop and more information would be known as the technology matures. In some situations, Pressure from external forces may also be used to address the attitude of non-innovativeness.

Other issues are the supports in terms of management and expertise in facilitating the pre-investment evaluation and trial. The ability to trial the technology helps to position the companies in terms of how RFID can be deployed to yield the required benefits. It can also be used to address the reliability problems by assessing the Compatibility of RFID with other existing systems. Management could play a vital role in supporting the investments if there is a business case to adopt RFID. This can be done by creating ability within the company to carry out trials, research, and other Facilitating Condition in the process of adoption. The lack of expertise is seemed to have hindered the implementation of RFID. There are limited number of vendors, especially in New Zealand, with the adequate experience and knowledge to implement RFID/SC. Most of the vendors are new organisations or new to selling RFID. Thus, similarly, the RFID vendors rely on trials and ability as do their customers. Last but not least is the concern of privacy which the issue is the collection and usage of personal information.

2.7.2 Requirements

This section explains the selection of requirements of RFID/SC adoption. For the purpose of finding out how organisations adopt and not adopt RFID technology in their supply chains, an understanding of what prior research has found important would help to define and ascertain the extent of this study (Yin, 2003). "Understanding the development history of an instrument is important in assessing its validity" (Moore & Benbasat, 1991, p. 194). Ten factors were selected as the enablers. Each of the factors is selected because they are either found as significant predictors of intentions and usage in IS adoption or are highly relevant from the point of view of this research based on the literature review. Their empirical findings by other research studies supports their validity in IS adoption. The ten factors are Compatibility, Relative Advantage, Pressure, Readiness, Subjective Norm, Facilitating Condition, Maturity, Motivation, Ability, and Privacy. Table 2-10 shows the articles that have used and found the respective factors significant or important in their studies.

Compatibility

Table 2-10 shows that Compatibility is one of the most frequently used and found to be influential factors in explaining technology adoption. Agarwal and Prasad (1997) found it to be important for predicting current usage. Rogers (1995) describes Compatibility as "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (p. 240). This is thus an important factor as it measures the degree to which the technology fits within organisations and processes. Applying this to the TOE framework, Compatibility is defined as the degree to which a technology is perceived as consistent with existing technological standards, organisational values and needs of potential adopters which includes other supply chain members.

Model	Variable	Source
Technology Adoption Characteristics	Compatibility	1, 2, 9, 14, 15, 22, 23, 25, 27, 29, 30, 31, 34
	Relative Advantage	1, 2, 3, 4, 6, 8, 15, 18, 21, 23, 25, 32, 35
	Pressure	2, 4, 6, 8, 15, 18, 21, 24, 26, 27, 31, 32
	Readiness	2, 4, 6, 8, 14, 15, 18, 21, 34
	Subjective Norms	5, 11, 31
	Facilitating conditions	2, 6, 16, 18, 22, 23, 26, 27, 29, 31, 33
	Maturity	27, 28
	Motivation	7
	Ability	7
	Privacy	-

Author	Code	Author	Code	Author	Code
Agarwal & Prasad (1997)	1	Gallivan (2001)	13	Premkumar et al. (1994)	25
Al-Qirim (2005)	2	Goodhue (1995)	14	Premkumar et al. (1997)	26
Amoako-Gyampah & Salam (2004)	3	Iacovou et al. (1995)	15	Ramamurthy et al. (1999)	27
Beckinsale et al. (2006)	4	Jimenez-Martinez & Polo-Redondo (2004)	16	Raymond (1990)	28
Brown et al. (2002)	5	Knol & Stroeken (2001)	17	Rogers (1995)	29
Chau & Hui (2001)	6	Kuan & Chau (2001)	18	Singh et al. (2007)	30
Christensen et al. (2004)	7	Lippert & Forman (2006)	19	Taylor & Todd (1995)	31
Chwelos et al. (2001)	8	Mahmood & Becker (1986)	20	Teo et al. (2003)	32
Cooper & Zmud (1990)	9	Mehrtens et al. (2001)	21	Venkatesh et al. (2003)	33
Daugherty et al. (1995)	10	Moore & Benbasat (1991)	22	Zaltman et al. (1973)	34
Davis et al. (1989)	11	Plouffe et al. (2001)	23	Zhu et al. (2006)	35
Fichman (1992)	12	Premkumar & Ramamurthy (1995)	24		

Table 2-10: Factors and Cited Research

Relative Advantage

Relative Advantage is another proven predictor of innovation adoption. It was found to be a dominant predictor of future usage by Agarwal and Prasad (1997). Rogers (1995) defines

Relative Advantage as "the degree to which an innovation is perceived as being better than the idea it supersedes" (p. 229). Other researchers associate it with the notion of benefits (Iacovou, et al., 1995; Taylor & Todd, 1995) and perceived usefulness (Agarwal & Prasad, 1997; Moore & Benbasat, 1991). Moore and Benbasat (1991) redefine the construct to include the meaning of using it as a perception of using an innovation. Based on these empirical suggestions, the perceived benefits and perceived usefulness can be used as a measure of Relative Advantage. Amoako-Gyampah and Salam (2003) in the study of ERP find that perceived usefulness is an important antecedent to the attitude towards systems usage. They also find that shared-beliefs influences perceived usefulness. In the RFID adoption environment, shared-belief is a crucial factor simply because it involves multiple players or supply chain members. Using the TOE framework, Relative Advantage is defined in this research as the degree to which using a technology is perceived as beneficial to the organisation and its performance.

It is worth noting that Moore and Benbasat (1991) suggest there is a high correlation between Compatibility and Relative Advantage. This means that the distinction between the two factors may not be clearly understood by users. In this research, Compatibility is referred to more as user evaluation of how compatible the RFID technology is to their TOE dimensions while Relative Advantage is the perception of the benefits of RFID technology. For example, Moore and Benbasat (1991) suggest demonstrability and visibility as two independent variables. It is however argued that the benefits of RFID are the ease of demonstrating how RFID works and showing the visibility of results. Thus Relative Advantage may cover a wide range of perceived benefits including result demonstrability and visibility as in Zaltman et al. (1973).

Pressure

In the study of diffusion of innovation at the organisational level, Pressure as a predictor is commonly investigated, particularly, external pressure. External pressure comes from various sources, from customer requests or competition pressure. Chwelos, Benbasat, and Dexter (2001) identify external pressure from three different sources: competitive pressure, industry pressure, and dependency on trading partners. In their study of EDI adoption, competitive advantage and enacted trading partner pressure were found positively significant on the pressure to adopt EDI. Similarly, Iacovou et al. (1995) found that small organisations are more likely to adopt EDI in a more competitive environment and especially from EDI initiator partners. In their study of EDI adoption by suppliers to the British Columbia Government, Iacovou et al. (1995) suggest that the perceived dependency on the Government corresponds to the likelihood of adoption, that small organisations are willing to adopt EDI as their business is highly dependent on their trading partners. In the case of RFID, suppliers highly dependent on Wal-Mart were somewhat willing to adopt RFID as a mandate (Premkumar, Ramamurthy, & Crum, 1997) or coercive pressure (Teo, Wei, & Benbasat, 2003). As there are several sources of pressure, the definition of Pressure as a factor of IS adoption requires clarity (Mehrtens, Cragg, & Mills, 2001). This added support that the TOE framework enables researchers to assess three different situations of Pressure. Hence, Pressure is defined in this research as the degree to which the intention to adopt a technology is perceived to be influenced by an organisation's network.

Readiness

Readiness as a factor is measured by the availability of technological and financial resources (Kuan & Chau, 2001; Mehrtens, et al., 2001). The availability of resources is particularly important to small organisations where resources are usually limited. Mehrtens et al. (2001)

measure technological Readiness with the level of IT usage and knowledge in organisations and Kuan and Chau (2001) with an additional measure of IT management in organisations. Iacovou et al. (Iacovou, et al., 1995) added that trading partners' Readiness is equally important. In the financial aspects, most research studies found no significant impact of finance on IS adoption (Iacovou, et al., 1995; Kuan & Chau, 2001; Mehrtens, et al., 2001; Raymond, 1990). Several reasons have been suggested. One of which is that the link of perceived costs of adoption to the behaviour could explain the low explanatory power of financial readiness. In some cases, organisations with more financial ability have a lower adoption rate. Iacovou et al. (1995) found the opposite where two organisations with high organisational readiness scores were less likely to adopt than another two with lower Readiness scores. They point to the dependency on partners as the overriding factor in their study of EDI adoption. Similarly in the case of RFID/SC adoption, organisations would depend on supply chain members for the integration of systems. Non-adopters might find information about the adoption from other adopters in their supply chains (Chau & Hui, 2001). Technology infrastructure as a Readiness factor has been found more significant between the two constructs by Zhu et al. (2006). Given the above explanation, Readiness in this research is defined as the degree of perceived availability of resources and technical support for technology adoption.

Subjective Norm

While the TAM may not be suitable in mandated situations, the additions of behavioural controls and Subjective Norms have been found significant in IS adoption (Brown, et al., 2002; Taylor & Todd, 1995). "Subjective norm reflects what an employee believes others (peers or superiors) think he/she should do" Brown et al. (2002, p. 291). Davis, Bagozzi, and Warshaw (1989) found that a Subjective Norm does not provide a significant measure in

cases where the IS is personal and individual. The social influence is less obvious than in IS which supports multi-user engagements. Therefore, a Subjective Norm is still a valid factor in organisational IS adoption and especially so in RFID/SC where it involves multiple supply chain members. The perceived normative beliefs formed by members around work-related settings are key to performance (Taylor & Todd, 1995). The use of TOE set the normative beliefs in the three different dimensions. Therefore Subjective Norm is defined in this research as the degree of perceived social influence on technology adoption. Social influence could include information about the technology advocated by certain important referents.

Facilitating Condition

Facilitating condition is defined by Venkatesh, Morris, Davis, and Davis (2003) "as the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system" (p. 453). This is similar to the Readiness constructs used in this research. However, referring to the items used by Venkatesh et al. (2003), Facilitating Condition seems to measure Compatibility, Knowledge, and Resources of using IT systems as compared to IT infrastructure per se. Taylor and Todd (1995) define Facilitating Condition with two dimensions: organisational resources such as time and money, and technological compatibility. They found that the resource Facilitating Condition had indirect effects of behaviours but the technical Facilitating Condition was not significant to behaviours. Although it was not clear what caused the non-significance of the technical Facilitating Condition factor, it could be related to the use of Compatibility, which explained attitude, as the competing variable.

It is clear, however, that the use of competing variables can reduce the predictive power of variables that are intended to otherwise predict behaviour. For example, Venkatesh et al.

(2003) and Moore and Benbasat (1991) performed a few iterations of pilot tests before concluding their empirical findings with satisfactory results. During the iterations, Moore and Benbasat (1991) found that trialability was grouped with voluntariness, and observability was grouped with result demonstrability which both show the overriding values of competing variables. Since Compatibility and Readiness are used to measure fitness of technology, and existing infrastructure to support adoption respectively, the use of Facilitating Condition in this research is designed around resources that facilitate the adoption of RFID/SC. Thus Facilitating Condition is defined as the degree to which technical, organisational, and external support that facilitate the adoption of a technology are perceived to be available. The trialability of a system facilitates adoption at a later stage (Jimenez-Martinez & Polo-Redondo, 2004). Therefore trialability fits into the technological dimensions of Facilitating Condition. Complexity was used as an independent variable in a diffusion of innovations study (Rogers, 1995). It is defined as the degree to which an innovation is perceived as difficult to understand, learn, and use. Mehrtens et al. (2001) found in their study of internet adoption that small organisations are lacking the knowledge that could facilitate rapid adoption. Thus, knowledge or subject expertise is important as a facilitator. Ramamurthy et al. (1999) found resource intensity as one of the key influences of EDI diffusion. It could be internal or external resources allocated to facilitate diffusion. With this argument, knowledge or expertise (Mehrtens, et al., 2001; Ramamurthy, et al., 1999) is the variable for the organisational dimension while vendor support (Al-Qirim, 2005; Chau & Hui, 2001) is for the environmental dimension.

According to Moore and Benbasat (1991), trialability had a relatively low reliability score. This could be due to the interference from other competing variables used in the same study such as result demonstrability or voluntariness.

Privacy

Privacy as an independent variable has not been studied in the IS adoption literature. It has however been examined as an endogenous variable. For example, Zhu and He (2002) found that the use of the Internet has impact on the concerns for privacy. Privacy is one of the few matters that were of concern to policy makers (Culnan, 2000; Rodríguez-Ardura, Meseguer-Artola, & Vilaseca-Requena, 2008) but somewhat of less concern to users (Sheehan & Hoy, 2000; J. Zhu & He, 2002). In the literature review on RFID, Privacy is also a common concern among policy makers and the general public (Good, et al., 2004; Jones, et al., 2004; Kelly & Erickson, 2005). However, for industry, privacy concern has been a secondary priority in terms of importance. Nevertheless, given that the concerns on privacy have slowed the adoption of RFID in Europe, it has become the intention of this research to examine Privacy concern as an independent variable that potentially may be hindering the adoption of RFID/SC in New Zealand. In this research, Privacy concern is defined as the degree to which the use of a technology is perceived as not conforming to the general privacy policy used in the organisation.

Maturity

Maturity has been posited by Ein-Dor and Segev (1978) to promote the success of IS implementations. It is defined as the degree to which "systems are formalized, quantified and produce data appropriate to their decision and control processes" (Ein-Dor & Segev, 1978, p. 1071). Thus, it is related to organisation structure. In the organisation theory literature, formalisation and decentralisation of an organisation structure can either hinder or promote the success of IS implementation (Hall, 1982; Zaltman, et al., 1973). For example, Ein-Dor and Segev (1978) found that less formalised organisations are less likely to succeed in IS

implementation while Zaltman et al. (1973) found that formal organisation structures "prohibit decision makers from seeking new sources of information" (p. 138). They suggest that at different stages of adoption, the relationship between organisation structure and innovation should vary to promote IS adoption. In the initial stage, a less formalised structure is more appropriate while during implementation a more formalised structure is necessary to get the process, policy, and resources established. As such, Maturity involves a collection of organisational constructs. Nevertheless, in relation to other factors studied in this research, Maturity has been related to Compatibility, Facilitating Condition, and Readiness from organisation's perspective. The three factors could, to a certain extent, measure an organisation's capability and resources to carry out IS adoption, which in turn is related to its organisational structure. It should also be noted that measuring the maturity level of an organisation could be difficult.

Motivation and Ability

Motivation and Ability are two factors observed by Christensen et al. (2004) using the MAF to show how the two factors work in market environments where innovation thrives. They provide a two-by-two matrix for assessing the resourcefulness of organisations using Motivation and Ability as continuums. The framework also suggests the roles of government in the various quadrants. In the market environment, there are non-market forces that impede innovativeness, such as industry standards, unions, technological developments, work rules, and government regulations (Christensen, et al., 2004; Frankel, 1990). The lack of agreed standards, lack of expertise, and integration difficulty in RFID/SC adoption are examples of such non-market forces. Thus, Motivation and Ability are two relevant factors. However, Motivation and Ability seem to be general factors that can fall into the various categories of factors. For example, Ability seems to merge with the Facilitating Condition factor and

Motivation with Relative Advantage. In regrouping the factors, Motivation and Ability fit better as a higher hierarchy. That is, Compatibility, Readiness, and Facilitating Condition are grouped as the Ability category while, Relative Advantage, Pressure, and Subjective Norm fall into the Motivation category.

2.8 Summary

This chapter covers the main subjects of the research and provided a summary of the potential problems and issues of RFID in supply chains and, in particular, New Zealand supply chains. RFID is one of the AIDC technologies with applications in industries, offices and homes. It is fundamentally an electromagnetic technology used in electronic road toll collection, EAS, public transport ticketing, and access to premises. With the introduction of EPC for object identification, RFID has been promoted as a barcode replacement. While RFID is a more efficient technology in product identification, it is still more expensive than a barcode. Many believe that RFID will become widespread when its price reaches below five US cents.

RFID in supply chains gain widespread interest in the early 2001 when retailers started investing in RFID. The mandate given to Wal-Mart suppliers to adopt RFID has quickened the development of RFID in supply chains. The focus of using RFID was mainly for product visibility along supply chains. RFID benefits include supply chain visibility, labour efficiency, and improved order fulfilment. Being a fairly new technology for use in the supply chains, the key barriers are standards, costs, reliability, and privacy.

Besides these RFID related problems, other problems and issues specific to New Zealand supply chains are identified. These are New Zealand’s distance to markets, small size of

companies, knowledge of RFID, attitude of companies, top management support, and implementation process. Ten requirements to address problems and these issues are identified (Figure 2-16). The requirements are adopted from technology adoption models discussed in the chapter. They are factors that are hoped to define and ascertain how organisations adopt or not adoption RFID in their supply chains.

The next chapter describes the research problems and approach to be taken to find how to resolve the problems.

CHAPTER 3 – RESEARCH METHODOLOGY

3.1 Research Problems

The problems identified in Chapter 2 can be divided into three groups. First, companies were unable to find a business case for RFID adoption mainly due to a lack of apparent benefits in comparison with the costs of adoption. With the costs of implementation relatively unknown, it was perceived as an expensive investment due to the high cost of RFID tags. As such, management support for the business case was short-coming.

Second, teething issues were reported with the implementation of RFID in some trials. The lack of agreed industry standards, knowledge and expertise in RFID/SC seem to be the common themes for the reported implementation woes. There was a general lack of sophisticated supply chain technologies probably due to the lack of expertise in supply chain information systems and inadequate IT infrastructure to support advanced technologies in supply chains.

Third, most companies were aware of RFID technology but there were few signs of adoption and actual usage of RFID in an integrated fashion through the supply chain. Companies might be concerned with what their customers were demanding to make their own decisions on a RFID/SC technology. As a supply chain involves several members, companies might have preferential suppliers or customers and might be waiting for them on RFID/SC technology adoption decision. There was also uncertainty in what standards would be adopted in their supply chains. Members were fragmented and some isolated due to smaller size. The lack of incentive and the inability to see real benefits of RFID/SC might have also contributed to the few signs of adoption and actual usage.

In New Zealand, some companies did not proceed further with their trials citing issues such as integration and industry standards as their concerns. There has been publicity about companies trying out RFID to improve product on-shelf availability and carrying out closed-door experiments. However, there were no examples of successful implementation of RFID/SC reported in New Zealand when this study started. Thus, RFID/SC has enjoyed a short spell of interest amongst New Zealand businesses but the uptake of RFID/SC has been slow in New Zealand. This study of the New Zealand context can be adapted to other parts of the world with similar adoption rates of about 10-15 per cent (Butner, 2006; Vijayaraman & Osyk, 2006).

To find out what is hindering New Zealand companies from adopting RFID/SC, or whether there is any business case at all for adopting the technology, this research begins by looking at the benefits and barriers to initial adoption in New Zealand supply chains. The initial decision whether to adopt a technology or not is made at the management level in an organisation. The benefits and barriers are further explored to find out the requirements for the adoption of RFID in supply chains.

3.2 Research Objective and Research Questions

The primary research objective is to explain the adoption of RFID/SC and identify initial barriers to the adoption. In order to achieve this, the first step is to find out the views or perceptions companies have of RFID technology in supply chains. It is also necessary to understand the attitudes of supply chain managers and partners towards RFID because that is where the benefits of RFID would have the most impact. It is noted that there are initial barriers to the adoption of most technology implementation as revealed in the literature review. It is, therefore, critical to

look at the specific business benefits of, as well as barriers to, the adoption of RFID. Therefore, the objectives of the research are to find out the benefits and barriers, and ascertain how organisations make the decision to adopt or not adopt RFID technology in supply chains.

Research Questions

Three research questions have been identified.

1. What specific benefits can be achieved by organisations in using RFID?
2. What are the barriers to realising these benefits?
3. How and why do organisations adopt or not adopt RFID in supply chains?

The first question is to explore the potential benefits of RFID/SC that New Zealand companies can leverage to stay competitive locally and internationally. This is done by investigating the development of RFID in the global context to learn what others are doing and the benefits they are seeing. The second question is to uncover the barriers to realising these benefits. The literature review is the first source of information for these questions. A survey is then conducted to understand the status of RFID development in New Zealand. The third question is to explain the attitudes towards technology adoption to understand the initial resistance to deploy RFID. In order to explain the third question, an in-depth analysis of how organisations in New Zealand adopt RFID/SC technology using case studies is conducted. Therefore, case study research, coupled with an extensive literature review and a survey on adoption theories, are to be used to investigate and explain the adoption process in organisations.

The remainder of this chapter discusses the philosophical stance of this research and the selection of the research methods. The research design is also described including the designs of the survey and case studies.

3.3 Research Methodologies

Research in Information Systems (IS) has broadened from a technical focus to a focus on the relationship between IS and organisations (Myers & Avison, 2002). Quantitative and qualitative research methods are both now widely adopted in IS research. Initially dominated by quantitative research, IS research is increasingly being used and the importance of qualitative research is being accepted in the study of social and cultural phenomena (Markus, 1997; Myers & Avison, 2002). "All research (whether quantitative or qualitative) is based on some underlying assumptions about what constitutes 'valid' research and which research methods are appropriate" (Myers & Avison, 2002, p. 5). As this research is attempting to find out the social phenomena surrounding RFID adoption in supply chains, and IS and its context, a qualitative approach is deemed more appropriate.

This section examines the three philosophical perspectives and their approaches to qualitative research (Orlikowski & Baroudi, 2002). The approach taken is to delineate the philosophical perspectives through examining the ontological and epistemological stances of the researchers about the world as it is and beliefs about social reality and knowledge, respectively (Chua, 1986; Orlikowski & Baroudi, 2002).

3.3.1 Positivist research

Positivists generally assume that a fixed relationship exists within which the phenomena reside. This view has a strong reliance on factual accounts of the phenomena. Thus, positivist research tests theory in an attempt to increase predictive understanding of the phenomena (Myers & Avison, 2002; Orlikowski & Baroudi, 2002).

The ontological view of a positivist is that physical and social worlds exist independent of humans. Human action is intentional, and rational or bounded rational. The researcher's role is to discover the objective world using measurable instruments in a formal, 'auditable' data collection and analysis process by separating facts and value, or means and ends, as described by Orlikowski and Baroudi (2002).

3.3.2 Interpretive research

Interpretive researchers generally assume that "people create and associate their own subjective and inter-subjective meanings as they interact with the world around them" (Orlikowski & Baroudi, 2002, p. 55). Thus, interpretive researchers attempt to understand the phenomena by studying the meanings that people assign to artifacts (Myers & Avison, 2002; Orlikowski & Baroudi, 2002).

In an interpretive approach to ontology the social world is made up of individuals with a variety of forms of interaction, socialisation, and participation that result in a social system that is not 'given'. Rather than discovering an objective social world, as do the positivists, interpretive researchers choose to understand social reality through the interpretation of the "language and tacit norms shared by humans working towards some shared goal" (Orlikowski, 1993, p. 65).

3.3.3 Critical research

Critical researchers generally adopt the status quo, "that social reality is historically constituted and that it is produced and reproduced by people" (Myers & Avison, 2002, p. 7). The view is strongly bounded by forms of social, cultural, and political social practices in an organisation. Thus, critical researchers attempt "to reveal the historical, ideological, and contradictory nature of existing social practices" (Orlikowski & Baroudi, 2002, p. 56).

In a critical approach to ontology, things are not in isolation nor confined to a particular state (Chua, 1986; Orlikowski, 1993). Social relationships and organisational practices possess contradictions and new social forms take place constantly. In acquiring knowledge, there can be no theory-independent collection and interpretation of evidence to conclusively prove or disprove a theory" (Orlikowski & Baroudi, 2002, p. 72), and "the role of the researcher is to bring to consciousness the restrictive conditions of the status quo, thereby initiating change in the social relations and practices" (Orlikowski & Baroudi, 2002, p. 73).

3.3.4 Philosophical Approach to Research

The philosophical approach adopted in this research subscribes to that of interpretive research. Perhaps, the view of this research can be described as 'non-positivist' "in which facts and values are intertwined and hard to disentangle, and both are involved in scientific knowledge" (Walsham, 2002, p. 103). In order for the research to have a theoretical basis to start with, previous research is studied to take into account the knowledge contributed by those studies, "which creates a sensible theoretical basis to inform the topics and approach of the early empirical work" (Walsham, 2002, p. 103). The positivist approach to knowledge is based on

factual accounts, that is, knowledge consists only of facts. Often a set of constructs and instruments that is measureable and testable via hypothetic-deductive scientific explanation is developed. Since the interpretive researchers and positivists share the same belief that facts are knowledge, this research developed a set of possible 'constructs' that, according to previous studies, are key factors that have influenced technology adoption to a certain degree. This helped to define and ascertain the scope of this research (Yin, 2003). However, unlike the positivist approach, neither hypothesis nor measureable instruments are used in this research since the approach is interpretive.

While there may exist a set of social constructs in an organisation's technology adoption process, that is, a formal or informal adoption decision-making process in an organisation, the constructs are socially-derived and constituted by individuals or groups. Thus, while adopting a set of a priori constructs, the approach taken in this research is interpretive, based on the belief that reality is socially constructed. The approach is to consider the contextual events of organisational technology adoption leading to how organisations make the decision whether to adopt or not. Technology adoption theories used in previous studies are referred to and used to create the set of a priori constructs that is aimed at forming a sensible theoretical framework. Cautious that a "rigid a priori researcher-imposed formulation of structure" (Orlikowski & Baroudi, 2002) may limit the discovery of theory in an interpretive research approach, unstructured and structured questionnaires are used (p. 66). This provides a semi-guided process in capturing the meanings assigned by the participants to their interpretations of technology adoption. It added a certain degree of openness to the field data and allowed the iteration of data collection, analysis, and theory building (Walsham, 2002). The results of this research (discussed in Chapters 6 and 7) demonstrate this approach with the discovery of possible new themes that were not initially discussed.

3.3.5 Research Methods and the Theoretical Framework

Research Methods Overview

With the philosophical approach stated, this section looks at various research methods and the use of survey and case study is explained in the following section. Yin's (2003) comparison of case studies with other research strategies is discussed next, followed by Myers and Avison's (2002) comparison of case studies, action research, ethnographic research and grounded theory used in qualitative research.

Yin (2003) highlights three conditions to evaluate which research strategy to use: (1) the type of research questions posed; (2) the extent of control an investigator has over actual behavioural events; and (3) the degree of focus on contemporary as opposed to historical events (p. 5). Table 3-1 shows the conditions for the various research strategies.

Strategy	Form of Research Question	Requires Control of Behavioural Events?	Focuses on Contemporary Events?
Experiment	How, Why?	Yes	Yes
Survey	Who, What, Where, How many, How much?	No	Yes
Archival analysis	Who, What, Where, How many, How much?	No	Yes/No
History	How, Why?	No	No
Case study	How, Why?	No	Yes

Table 3-1: Relevant Situations for Different Strategies

Research questions can be classified into the what, who, where, how, and why inquiry forms. The 'what' questions attempt to discover or quantify a phenomenon. If the nature of the study is exploratory, any of the five strategies listed in Table 3-1 can be used. However, Yin (2003) suggests using survey or archival analysis if the questions are about 'how many' or 'how much'. Similarly, in the 'who' and 'where' situations, the objective of the research is to predict certain outcomes. Thus, survey and archival analyses are more favourable. In contrast, the 'how' and 'why' questions attempt to explain the phenomena. Such questions are, therefore, explanatory and bounded by time periods rather than frequency or incidence. Case study, experiment, and history are considered the more suitable research strategies in this case.

The other two conditions pertain to control over the behaviours and the time periods in which the events took place. In a research experiment, the researchers have control over the test and direct manipulation on the behaviours. An example is a laboratory test where there can be a control group in an experiment. Most research examines contemporary events. An exception is historical research where past events are studied. Archival analysis can be used for contemporary or historical research depending on the type of research questions.

Four qualitative research methods are described by Myers and Avison (2002). "Action research is an interventionist approach to the acquisition of scientific knowledge" and contributes to the knowledge community (Baskerville & Wood-Harper, 2002, p. 133). Researchers are expected to further enhance the development of theories. As its name implies, researchers are actively involved in the research and the knowledge obtained is immediately applied to link the theories and practices.

Case study research is one of the most commonly used research methods in IS (Myers & Avison, 2002; Orlikowski & Baroudi, 2002) and was found, by this research, to be a frequently described research method in the RFID in supply chain literature (refer to Appendix A). Case studies are suited for research into contemporary events and attempts to find out the 'how' and 'why' of a phenomenon. Case study research can be positivist, interpretive or critical (Myers & Avison, 2002).

Ethnographic research originated from the study of anthropology. Malinowski adopted the ethnographic research method to understand the culture of the Trobriand Islanders (Harvey & Myers, 2002). The approach requires the researcher to be immersed in the context of the study. "By learning the local language and living in a society for at least one or more years, by trying to understand the meaning of particular cultural practices in context, only then would other cultures and societies start to make sense to [foreign] observers" (Harvey & Myers, 2002, p. 174). Thus, ethnography is a rigorous approach to the analysis of the context and is useful when the researcher has little knowledge about the context.

The grounded theory approach attempts to develop theory that originates from the context studied. It is "an inductive, theory discovery methodology that allows the researcher to develop a theoretical account of the general features of a topic" (Martin & Turner, 1986, p. 141). According to Orlikowski (2002), the grounded theory approach produces accurate and useful results that incorporate the complexity of organisational change. The approach captures the sequence of events and social interactions in an iterative manner to develop theory that describes and explains the context studied.

Theoretical Framework Selection

The adoption of RFID in supply chains as a research area is fairly new. There were some empirical works around the barriers of RFID adoption (Angeles, 2005; Asif & Mandviwalla, 2005; Atkinson, 2004; Jones, et al., 2004; Twist, 2005), but no studies on the adoption of RFID at the organisational level had been found at the time of formulating the research questions for this thesis. Empirical research in RFID adoption started to emerge in 2007, thus, the number of empirical research studies on RFID that are available for reference is limited. As there was insufficient information on the adoption of RFID in New Zealand, the first step in the research is to find out what New Zealand companies are doing with RFID and how many companies are using RFID in their supply chains. This type of exploratory nature of inquiry calls for either survey or archival analysis. Since this is on contemporary issues, survey is favoured. Case study approach in this step may not provide a representative result given the narrow but in-depth inquiry nature of the approach. To get a large sample for case study is simply not feasible and is resource consuming. Thus, survey is the more appropriate method for Step 1. The objective of the survey is, therefore, to explore and ascertain the adoption status of RFID in New Zealand supply chains. The results of the survey is hoped to provide some direction on New Zealand's position in terms of RFID innovation and implementation. Conducting the survey has two advantages. First, it forms the basis for the design of the case study. The findings of the survey pointed the research towards investigating organisations' adoption processes. Second, it creates awareness of the RFID research work amongst New Zealand businesses. It is hoped that companies who participate in the survey will also participate in the case study. The survey is, thus, an approach to creating awareness and building relationships with industry. This approach may also pave ways for identifying relevant participants for the case study.

The next step in the research is to conduct an inquiry into how and why companies adopt or not adopt RFID/SC. The research is to cover various members in the New Zealand supply chains to find factors that might explain adoption of RFID/SC. The nature of inquiry in this step leans towards qualitative research. According to Yin (2003), experiment, case study and history are the three possible research strategies. Experiment approach often requires the researcher to control the behavioural of the events which is not desired in this study. History approach investigates past events and explains how and why they have occurred. Although history approach could be applied to a certain extent, it is not sufficient to explain contemporary events as is for this study. Thus, case study method is preferred as the purpose of this research is to investigate contemporary events and to answer the 'how' and 'why' questions in relation to the adoption of RFID.

While action research and grounded theory can be used, they require the researcher to spend an immense amount of time with the selected cases. Constant visits to the sites are required by both approaches to generate rigorous data collection and analysis, and record the flow between the two (Baskerville & Wood-Harper, 2002; Orlikowski, 2002). As this research has a well-defined objective of finding the factors affecting the adoption of technology by means of input from the survey, the researcher has become familiar with the topics and the context being studied. The subject of the study, supply chains, means that multiple case studies within the supply chains are required for a more descriptive theoretical outcome. Thus, action research and grounded theory are not practical given the large networked context involved and the limited time available for this research. Ethnographic research is certainly beyond the scope of this research since it demands more time and involvement with the cases than is feasible. Thus, case study methodology, in association with a survey, is determined to be the most appropriate methodology

for this study. The use of case study will present the ability to investigate multiple cases to find the factors affecting the adoption of RFID/SC technology in the supply chains.

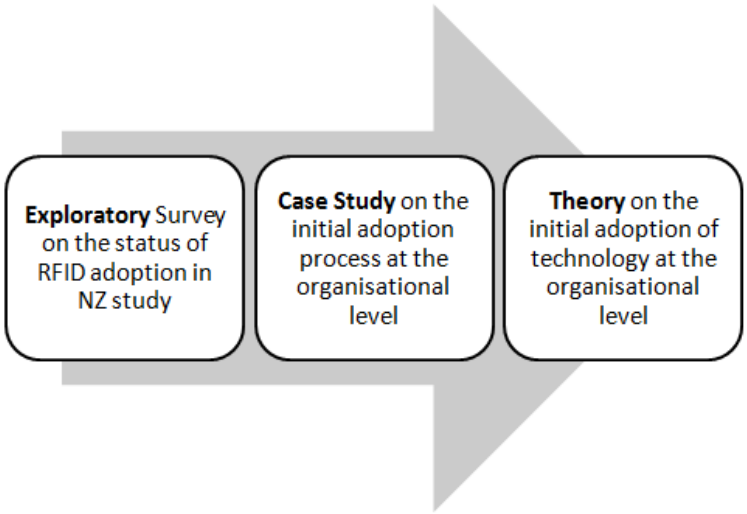


Figure 3-1: Research Process

Figure 3-1 shows the process of the research. The study started on a broad research domain. The exploratory survey is to help narrow the research area by raising questions specific to the primary adoption stage of technology diffusion (Gallivan, 2001). The use of case studies I sto explain the adoption with a more in-depth inquiry into the impact of RFID on logistics performance (Johansson & Pålsson, 2009). Pare and Elam (1997) state that "the gathering of both quantitative and qualitative data from multiple sources helped to demonstrate the extent of congruity and consistency between researchers' and key informants' evaluations of the IT implementation projects" (p. 551).

3.4 Research Design

In this research, technology adoption models are used to explain the phenomenon of RFID technology adoption behaviours in supply chains. The IS literature has a comprehensive pool of knowledge in IS adoption both at the individual and organisational levels. Organisation theory has also been used for the study of technology adoption by Rogers (1995). The IS and organisation theory pools of knowledge are adapted to explain technology adoption in the supply chain and operations management discipline. There are not many studies in the supply chain field that use organisation theory and IS adoption models to explain diffusion and implementation. Some examples are Premkumar et al. (1997) who employed innovation characteristics to study the determinants of EDI adoption; Lippert and Forman (2006) who used IS theory to study the diffusion of technology in supply chains; and, most recently, Stock and Tatikonda (2008) examined external technology integration success using organisation theory. It is, therefore, timely to look through an IS and organisation theories lens in the study of RFID/SC adoption. As explained earlier, the fusion of IS and organisation theories is expected to provide a more complete view of how organisations adopt technologies and contribute to the knowledge pool of the supply chain and operations management discipline. This section describes the research design.

The research is focused on the adoption of technology by organisations, and the units of analysis for the research are, therefore, supply chains in New Zealand. Supply chain is defined as a set of organisations that move materials, products, or services to market (LaLonde & Masters, 1994; Lambert, Stock, & Ellram, 1998). Organisation is defined as “a social system created for attaining some specific goals through the collective efforts of its members” (Zaltman, et al., 1973, p. 106). The theories adopted in this research are, thus, primarily organisational theories and are

sometimes referred to as the contingent authority innovation decision (Zaltman, et al., 1973). It is worth noting that in the decision-making process of an organisation, individual members, such as decision-makers, are instruments in the decision to adopt or not to adopt a technology. Organisational technology adoption is a collection of individuals' behaviour towards the intention to adopt the technology. Pfeffer (1982), in explaining organisation theory, suggests grounding organisation theory to social collectives' behaviours to explain events and processes occurring in organisations. Therefore, to find out how organisations adopt technology (IS), a wider view of the technology diffusion theory is taken.

Individual technology adoption theories, referred to as the traditional innovation adoption frameworks by Gallivan (2001), are also reviewed (Markus & Robey, 1988). Appropriate constructs from both the traditional innovation adoption and organisational technology adoption frameworks are selected to explain individual adoption decisions at the organisational level. Gallivan (2001) suggests using key constructs from the various research on "individual, workgroup, and company-wide innovation adoption and implementation" to reconcile the gap between the traditional and emerging organisational theories (p. 52). Markus and Robey (1988) "believe that mixing levels of analysis [at individual and organisational levels] may be useful in research and theory on information technology and organizational change" (p. 594). This approach takes a holistic view of decision-making by individuals in the context of business-influencing behaviour. Business-influencing behaviour refers to how decision-makers set their agenda according to organisational values and objectives. In the case of technology adoption, an example of business-influencing behaviour are the decision-makers' views of investment that impact on technology adoption decisions. So, how do decision-makers make decisions when it comes to adopting information technology? In the case of RFID, the adoption of RFID is potentially disruptive to an organisation's existing business processes (Soon & Gutierrez, 2009).

Therefore, it is critical for this research to adopt a well-tested adoption process framework to guide the inquiry into the decision-making process at the organisation level. Roger's five-stage innovation process model which describes the adoption process of an organisation is used for this purpose. It is, however, not the intention of this research to form a rigid structure but rather a framework that leads the research to a reference point, bearing in mind that the underlying philosophy taken is an interpretive approach.

3.5 **Survey**

The purpose of the exploratory survey is to find out the benefits of and barriers to the adoption of RFID in New Zealand supply chains. It is also to explore the extent of RFID adoption in New Zealand and create a database for following research. Thus, the survey is a preliminary study leading to the discovery of the factors of technology adoption for the second part of the research study. In order to capture a wide view, the sampling of the survey should include end-users of RFID, solution providers, as well as academics. The survey questionnaire consists of a total of 38 questions. The full set of questions is attached in Appendix B.

End-users will be asked for their reasons for adopting or not adopting RFID, their concerns when evaluating RFID adoption, and their perceptions on RFID adoption. The adopters will be asked how satisfied they are with their RFID implementation. The outputs of end-users will be a list of benefits and barriers to RFID adoption, and a list of the perceived difficulties or ease of RFID implementation. The RFID solution providers will be asked mainly about their knowledge of RFID and also about their customers' concerns and issues regarding RFID implementation. The academics will be asked about the type of research that they are working on.

Overall, the survey should provide an indication of the status of RFID/SC adoption in New Zealand at the time of survey. It should highlight the perceived benefits of and barriers to RFID adoption, what RFID solution providers are dealing with, and what aspects of RFID research are being carried out in New Zealand.

3.6 Case Study

The purpose of the case study is to conduct an inquiry into how organisations in New Zealand decide to adopt RFID technology. The case study hopes to show how and why an organisation might adopt radically new technology, and at what point the initial adoption would take place. The case study hopes to explain the behaviours surrounding the process leading to adoption and through to implementation.

The three elements identified in the literature review of technology adoption, namely, technological, organisational, and environmental will be explored in more detail through the case study.

The cases for the case study will be New Zealand companies involved in RFID/SC of some form. The term involve is used here to represent any type of RFID development within a company. A company could have implemented RFID, conducted a trial, or even just discussed RFID at the management level.

A total of twelve organisations are hoped to be selected for the study. The organisations are to be in the following category: four organisations in the supplier/manufacturer category, four organisations in the distributor/logistics service provider category, and four organisations in the

retailer category. This arrangement provides a balanced view from the cases. The design of the case study research, therefore, provides a holistic view of multiple-case research.

3.6.1 Preparation for Interviews

The interview consists of structured and unstructured questions. The requirements of RFID/SC adoption discussed in the literature review (Section 2.8) formed the set of constructs as a reference point for the case study. Three of the requirements – Motivation, Ability, and Maturity – are dropped to reduce the number of questions to be asked. Motivation and Ability which match the MAF are decided to be a superset of some of the other requirements. For example, Subjective Norm and Relative Advantage are considered as motivation factors while Facilitating Condition, Readiness and Compatibility are considered as ability factor. In the case of Maturity, it is decided that it will be difficult to measure the mature level of an organisation and its IT infrastructure. Hence, Maturity is dropped from the construct.

The constructs are developed into 23 questions as shown in Appendix D. Each question is coded and linked to the constructs. The questions are tested by a colleague, and a full interview process, including the completion of the survey, is simulated. This helped to develop a process by which the researcher is familiarised with the questions and prepared for any contingencies. An interview guide, using Roger's five-stage organisational innovation adoption process (see Appendix C for the interview protocol), is developed as part of the unstructured interview. The unstructured questions are used to explain the process of technology adoption as the main part of the study. The focus is on the agenda-setting and matching stages of the five-stage organisational innovation adoption process. For example, interviewees will be asked how RFID came to their attention and how they matched RFID with their problems.

3.6.2 Conduct of Interviews

The participants are to be asked to answer the 23 questions (Appendix D) before the actual interview. The results provided by the participants will be reviewed before the interview so that questions can be asked to clarify any patterns or trends found. The participants will then be asked the questions on the agenda-setting and matching stages (Appendix C).

3.6.3 Analysis of the Interviews

After each interview, the notes and answers to the questionnaire is to be coded. The data is to be uploaded to NVivo for textual analysis. In the case of uncertainty in the answers, the interviewees should be contacted for clarity. The results of the interviews are to be analysed by grouping the results into the three supply chain groups, namely, suppliers, distributors, and retailers so that the similarity and differences in each group can be derived and compared. Within groups and group-wise comparisons is to be made.

In validating the quality of the case study design, four case study research conditions (Yin, 2003) were noted and followed.

3.6.4 Construct Validity

An important aspect of a research effort is to form a set of operational measures (Yin, 2003). In making sure that the measures used in the study are relevant, an extensive literature review was carried out and multiple sources of evidence were used. The literature reviewed was primarily on the adoption of EDI and other organisational applications. Besides using past research studies,

organisations within New Zealand were studied to establish their contribution to the research. The primary sources for this study were the web sites of the participating organisations and information on their participation in RFID-related events such as the GS1 New Zealand RFID Pathfinder Group's events.

3.6.5 Internal Validity

In order to avoid reaching the wrong conclusions from the interviews, a researcher requires extensive knowledge on the subject and its context. In an effort to establish better knowledge of New Zealand RFID development, the researcher has been actively participating in RFID events in New Zealand and getting to know the organisations involved. Knowing the background of the organisations before interviewing them helps to minimise the risk of having preconceptions that might lead to making wrong inferences.

3.6.6 External Validity

Use of the simplified supply chain model for the selection of cases minimises the possibility of criticism of whether the findings are generalisable beyond this study. Yin (2003) argues that, in case studies, an analytical generalisation approach can be used to generalise the results to a broader set of the theories. However, in this research, a survey has been used to provide a statistical generalisation of the results from the case study. This approach provides two validations. First, it validates the extent of the research results to its immediate broader theory. Second, it validates the applicability of the research results to the adoption of technologies in an organisation. Thus, it demonstrates the replicability of the research design.

3.6.7 Reliability

The data collection procedure was documented before the interviews were carried out. The researcher was guided by a set of semi-structured questions and a framework for the interviews. The questions were revised by experts in the field including the researcher's supervisor. A pilot case study was conducted to test the interview design and to establish a sensible set of questions. During the conduct of the interview, whenever new findings that were important to the study were uncovered, the findings were included as questions in the subsequent interviews.

3.7 Summary

This chapter outlines the research area and methodologies to be adopted. The purpose of the research is highlighted with three research questions. The study adopts an interpretive research methodology with exploratory survey and case study as the research methods. This chapter also discusses the purposes of the survey and case study and how they will be conducted. The validity and reliability of the research are also described. The remainder of the thesis covers the results and discussions of the survey and case studies.

CHAPTER 4 – EXPLORATORY SURVEY

4.1 Purpose and Conduct of Survey

The purpose of the exploratory survey is to find out the benefits of and barriers to the adoption of RFID in New Zealand supply chains.

The sampling of the survey included end-users of RFID, solution providers, as well as academics. There are a total of 38 questions in the survey. The full set of questionnaire is attached in Appendix B.

The survey was conducted using on-line surveys over a period of six weeks. Invitations to fill out the survey were sent out to users/potential users of RFID technology, as well as to several lists of members of the Chartered Institute of Logistics and Transport in New Zealand, the New Zealand Trade Enterprise, the New Zealand Retailers Association, and the Wellington Chamber of Commerce with a potential sampling size of about two thousands. A total of 105 responses were received, of which 66 were complete and without error.

The respondents had a good mix of roles within the supply chain organisations in New Zealand. About 44 per cent of the respondents were from Small/Medium Enterprises, 24 per cent from Multi-National Corporations, and ten per cent from academics. In terms of the number of employees, 45 per cent of the respondents were from companies with more than 200 employees. The respondents represented a range of industries: a large number of the respondents were from the ICT sector followed by the retail, education, manufacturing, wholesale trade and business services industries.

The design of this survey allows RFID adoption to be examined from the perspectives of the following three groups:

- End-users of RFID in supply chains,
- RFID solution providers and,
- Academic institutions.

The end-users can be further distinguished as adopters and non-adopters. Adopters are those who have adopted or are planning to adopt and test RFID while non-adopters are those not adopting but they may have the intention to do so over the next three years. The decision to include RFID solution providers' and RFID researchers' (based at academic institutions) opinions is mainly to understand from their perspectives the development of RFID innovation and the availability of hardware, software, and solutions in New Zealand. RFID, at its early stage of development, requires innovative applications that businesses can profit from. The RFID solution providers and academic institutions are in the position to accelerate such innovation and help to reduce the uncertainties associated with adopting the technology that businesses may have. They could also help to organise information, identify met and unmet needs and any gaps that exist between the adopters and the non-adopters in New Zealand. Thus, the survey's findings are best examined by separating out the three groups of respondents.

4.2 Overview of Survey

The survey results indicated that the adoption of RFID in New Zealand was at an early stage. Although there were leading trials and the technology had been well publicised in the country, most local companies did not have RFID in their investment plans. The primary barriers to

adoption are the high costs, lack of agreement on standards, lack of integration, and lack of knowledge or expertise in the technology. The survey also revealed the dissatisfaction of the early adopters and the different adoption trends along the supply chain. There is thus an urgent need to address the satisfaction level of RFID implementation in order to facilitate the uptake of RFID in New Zealand and around the world.

The rest of this chapter discusses the results of the survey and then compared with other similar surveys. The chapter concludes with a summary and an introduction to the case study that follows this survey.

4.3 Survey Results

4.3.1 End Users

The majority of the end-user respondents were in the business of manufacturing, supply and production (21 respondents), warehousing, distribution and transportation (10), or retailers (10). Thirty per cent of the end-users said they were either adopting or planning and testing prior to adopting RFID. However, at least 34 per cent of the respondents were not adopting and did not have the intention to adopt RFID (see Figure 4-1).

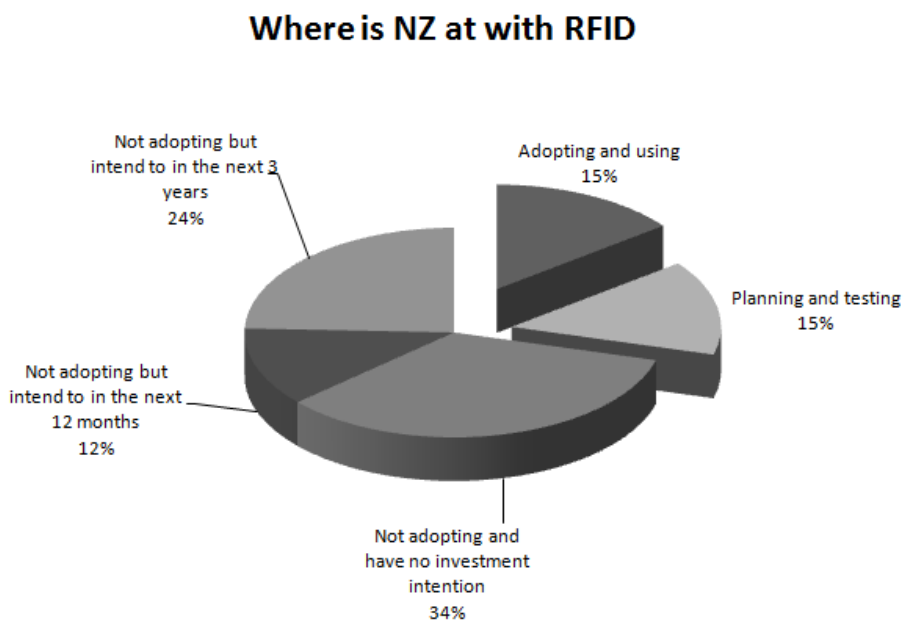


Figure 4-1: RFID Adoption Status in New Zealand

When asked the reasons for adopting or not adopting RFID, the adopters stated the following:

- Better inventory visibility,
- Improve labour efficiency,
- Product traceability requirement and,
- Speed up order fulfilment

Figure 4-2 shows the reasons for adopting RFID.

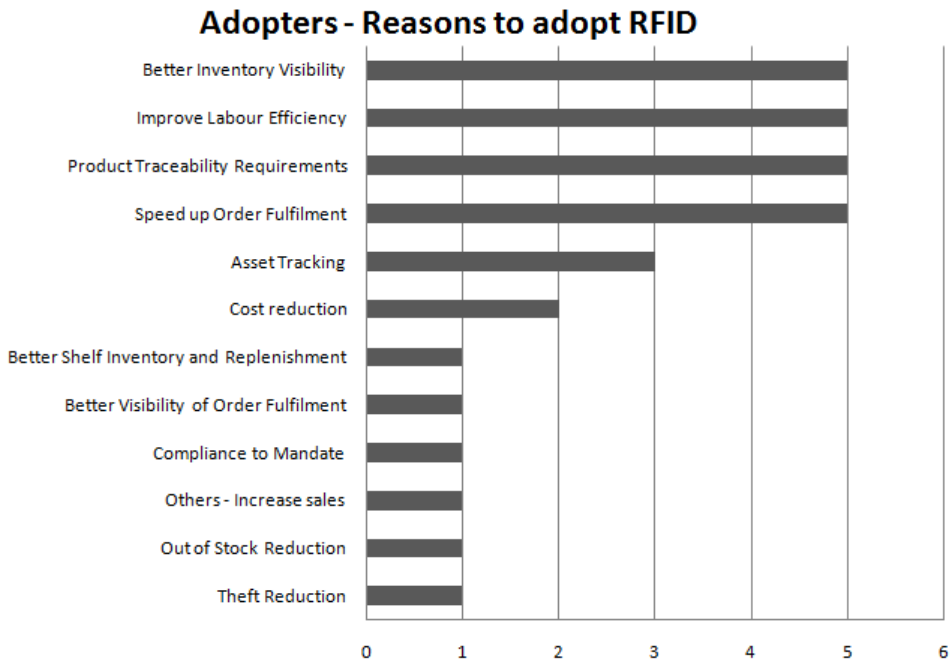


Figure 4-2: Reasons to adopt RFID

A closer look at these responses revealed that the adopters who perceived benefits of better inventory visibility also required product traceability at some stages of their supply chains. The manufacturers, suppliers, producers and retailers made up the majority of the adopters reporting the above reasons for adopting the technology. Similarly, respondents who reasoned that RFID improves labour efficiency also believed that it will speed up order fulfilment. The warehouse, distributors and transporters made up the bulk of the adopter respondents giving such responses. Thus there are two RFID adoption trends in New Zealand industry: (1) improving product visibility and traceability, and (2) improving labour efficiency and order fulfilment.

To the same question (the main reasons for adopting and not adopting RFID), the non-adopters reported the main reasons for not adopting RFID were:

- Lack of agreement on standards,
- Lack of integration, and
- Lack of expertise/knowledge.

Figure 4-3 shows the reasons for not adopting RFID.

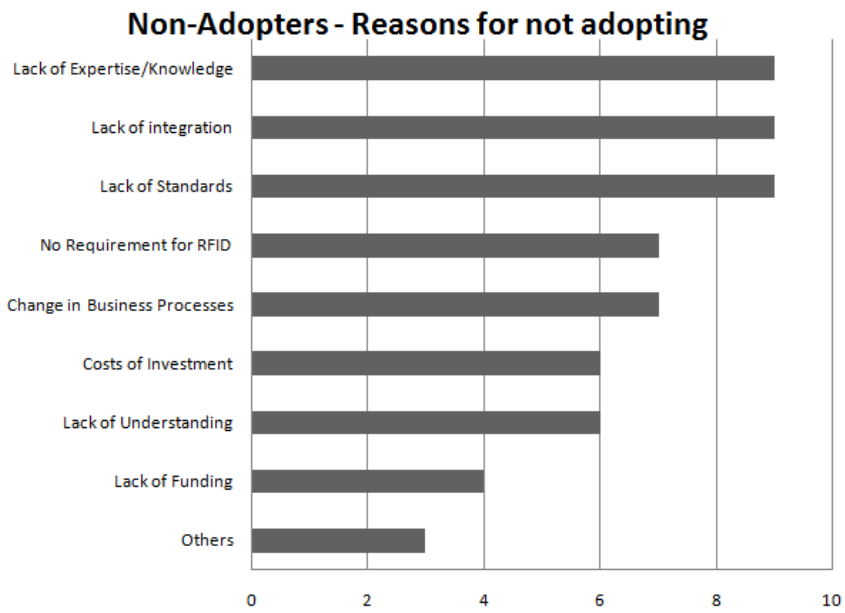


Figure 4-3: Reasons for not Adopting RFID

The commonality between the adopters and non-adopters is their concern over the high investment cost including such issues as the cost of the tags, systems integration, and the upgrading of existing infrastructure.

In addition to investment cost, the non-adopters were also concerned about the compatibility of standards and the accuracy of scanning at their sites. An analysis between the adopters and non-adopters revealed four concerns that were different between the two groups. The adopters were generally not so concerned about the following:

- Compatibility of standards,
- Security of data,
- Difficulty with scanning accuracy at their sites and,
- Usefulness of data collected by RFID.

As early adopters, they would have already investigated and tested the technology and thus were at ease with the technical aspects of RFID. The non-adopters in contrast might not have sufficient knowledge about the technology leading to an unclear perception of how the technical difficulties may be overcome. Nevertheless, when asked to evaluate their satisfaction with their RFID implementation, the adopters ranked the standards compatibility issue as not so satisfactory; it did not meet their expectation during implementation, although they were not concerned about the compatibility of standards. The adopters were also not so satisfied with the overall integration achieved and only somewhat satisfied with their investment costs. Thus the non-adopter's concerns over investment costs and compatibility of standards seem to be valid.

The reported investment in RFID was not substantive. Sixty per cent of the adopters had invested less than New Zealand $20,000. When asked about future investment, 40 per cent of the adopters intended to invest not more than New Zealand $50,000 while 30 per cent had no further investment intention. Thirty per cent of the non-adopters indicated that they intended to invest not more than New Zealand $50,000 and 50 per cent had no further investment intention.

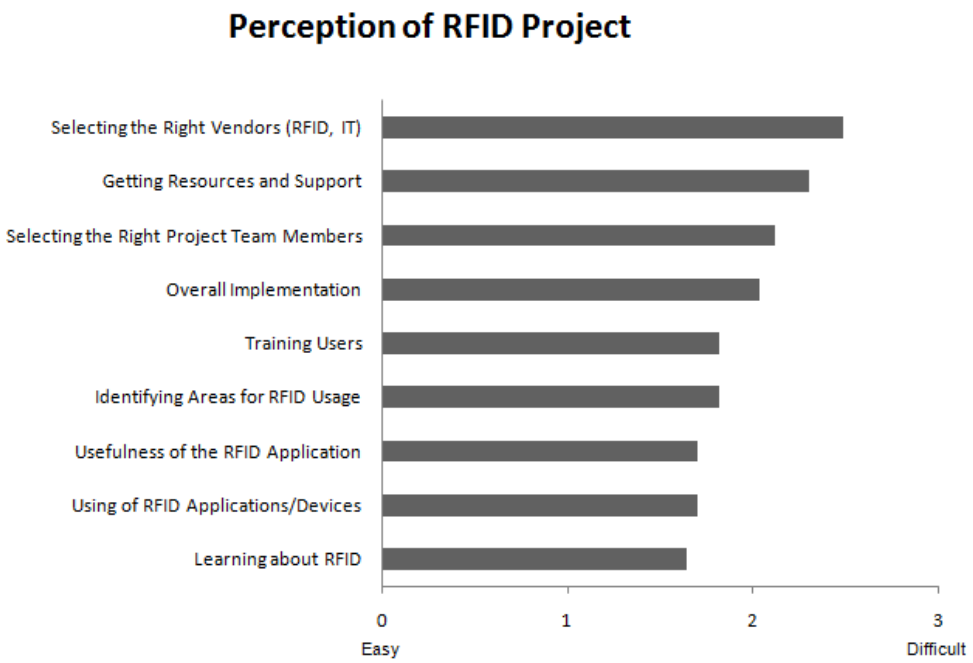


Figure 4-4: Various Aspects of RFID Project (End Users)

Of interest is the end-users' perception of the various aspects of RFID adoption. Both the adopters and non-adopters perceived selecting the right project team members, selecting the right vendors (RFID/IT), and getting resources and support for the project as imperative and yet difficult compared to the other aspects shown in Figure 4-4.

On benefiting from RFID, about 60 per cent of the respondents believed that the warehousing, distribution and transportation group will benefit most from RFID implementation. This is contrary to another independent study conducted in 2005, in the United States, whereby a majority of the respondents believed that retailers will benefit most from the technology (Vijayaraman and Osyk, 2006).

4.3.2 RFID Solution Providers

Seventeen RFID solution providers responded to the survey; the majority of the respondents indicated that they provide application software and project management services. Other services offered include IT integration, hardware, process mapping, business case analysis and advisory services.

To the question on companies' competency, results saw understanding of user's requirements for RFID yielded the highest score. This was followed by Electronic Product Code (EPC) compliance, data management, and physical aspects of RFID. Most of the respondents were modest about their knowledge of RFID integration with existing systems and business process solutions.

The solution providers reported reasons similar to the end-users for implementing RFID in the supply chain, with the exception of asset tracking, which the solution providers believed was one of the primary reasons for adopting RFID. Also comparable was the extent of concern expressed by the solution providers' customers and the end users. Investment cost was notably the aspect with the highest reported concern followed by scanning accuracy at site.

In the actual implementation of RFID, the solution providers indicated no difficulty with compliance or availability of standards and with user training. They informed that integrating with existing systems was a more difficult task.

4.3.3 Academic Institutions

Eight academics responded to the survey. Although there were not many RFID courses available, 50 per cent of the academic respondents revealed there was on-going research on RFID of various sorts. However, only two New Zealand universities were offering RFID courses at the under-graduate level. Also, most of the research projects at the university level did not appear to be extensive at this stage although several universities maintained that RFID software application, data management, and privacy issues were being extensively studied. The more popular RFID research projects typically revolved around the physical aspects of radio frequency and RFID in the supply chain.

4.4 Comparison with Other Surveys

This section looks at the key differences between this survey and other similar recent surveys. It draws comparison with other regions in terms of RFID adoption. The percentage of companies adopting and not adopting RFID in New Zealand is close to the results of most other surveys. Vijayaraman and Osyk's (2006) study of RFID implementation in the warehousing industry in the United States reveals about 14 per cent of the respondents were implementing RFID. In another survey by IBM (Butner, 2006), 70 per cent of the respondents were not implementing RFID which was also the case in New Zealand.

In terms of the reasons to implement RFID, compliance requirements top the list in the United States and Europe (Butner, 2006; Vijayaraman & Osyk, 2006). At the moment, there is no compelling requirement for companies in New Zealand to implement RFID. A possible such requirement in New Zealand would be to trace meat in the primary produce sector (Anonymous, 2005). Other prominent reasons from overseas to adopt RFID were better inventory visibility and

labour efficiency (Vijayaraman & Osyk, 2006). For retailers, supply chain visibility was one of the leading reasons to implement RFID (ABIResearch, 2006; Butner, 2006). This is similar to the trend in New Zealand where product traceability is an important criterion when planning an RFID project. In the case of not adopting RFID, investment cost and standards were the common reasons for companies not to adopt RFID. A concern that is revealed in this survey is the satisfaction of RFID implementation. Most respondents were not so satisfied with the components they initially ranked as not a concern. In the other surveys, it is also found that adopting companies did not have a high satisfaction level with their RFID implementation (ABIResearch, 2006; Vijayaraman & Osyk, 2006). Thus these surveys, including this study, indicate that there is a need to address issues that lead to low satisfaction level.

4.5 **Summary**

It is the aim of this study to help form an understanding of the issues surrounding RFID adoption in supply chains. It is clear that there is a lot of interest in RFID although the adoption rate is low. Only 15 per cent of the respondents were using RFID and about 34 per cent did not have the intention to adopt RFID at all. The rest of the respondents were either testing or planning to adopt. On the whole, about 70 per cent were not yet adopting the technology. The survey results provide valuable insights into the barriers facing RFID adoption. The lack of agreement on standards, integration, and expertise seem to be the main deterrents holding potential users back from taking up the technology. These concerns, while valid, can be remedied through providing adequate education in ways that support technology assimilation. The academic institutions and other organisations, such as GS1/EPCglobal, can come in to help inform potential users about the technology and its potential benefits to businesses.

A study like this can indeed help shed some light on the factors that may have impeded the diffusion of RFID in New Zealand. The adopters and non-adopters differ in the extent of concerns around issues such as standards compatibility, data security, scanning accuracy, and the usefulness of data. Providing information of these factors relevant to each group can, on top of alleviating their reservations, help the non-adopters to better understand how RFID can be designed to suit their operations and business values.

Low satisfaction levels experienced by the adopters can potentially slow the diffusion of the RFID technology. This is not unexpected given that the adopters were generally not so satisfied with their overall integration and the compatibility of standards. And as it is, about 30 per cent of the adopters indicated no further investment planned, while 40 per cent would invest no more than New Zealand $50,000 in their next project. The adopters' experience with their first RFID projects had different impact on their future investment plan. Attention to the costs of investment is not unwarranted. In particular, the following two cost-related concerns are worth pointing out: cost of tags and systems integration.

On top of everyone's list when deciding on RFID projects was the cost of investment. Investment cost is an important consideration and often an impediment to any technology adoption. There are numerous research projects on reducing the cost of RFID tags. More research attention is warranted to evaluate the cost of systems integration particularly in the area of fitting RFID systems into existing infrastructure and legacy systems.

Research has shown that in technology adoption, the user perception of the technology affects the decision to adopt and subsequently to diffuse the technology within their organisation. The results of this survey revealed that the selection of the right project members and RFID vendors, and

getting required resources and support were perceived as necessary and difficult tasks. Results gathered from the RFID solution providers presented some useful information on the type of providers and services available in New Zealand. The providers are by and large competent in the technology and have sufficient knowledge to help local businesses embrace the technology. More can and should be done to follow up with this exploratory information on the adoption of RFID in New Zealand as presented by this study. Several questions still remain to be answered. From the findings of this survey, the questions that need further investigation are:

1. Are the lack of agreement on standards, integration, and expertise the true technology barriers to RFID adoption?
2. How important is investment cost to an organisation when evaluating RFID in supply chains?
3. What are the motivational and ability factors that drive RFID in supply chains adoption?
4. How does an organisation proceed with the assessment of RFID in supply chains that leads to the decision to adopt or not to adopt RFID?

To answer these questions, an explanatory research study is required. One approach is to conduct a constructive case study research inquiring into how an organisation adopts technology. Of interest is the need to look at the characteristics of the early adopters and non-adopters, taking into consideration the technological, organisational, and environmental factors that affect technology adoption and diffusion. Thus, the rest of this thesis will focus on the adoption of RFID technology at an organisational level using case studies.

The following chapters analyse and discuss the findings in the case studies.

CHAPTER 5 – CASE STUDY ANALYSIS

5.1 Purpose and Conduct of Case Study

The purpose of the case study is to conduct an inquiry into how organisations in New Zealand decide to adopt or not adopt RFID technology. The case study is hoped to show how and why an organisation might adopt radically new technology, and at what point the initial adoption would take place. The following sections described how the cases were selected and how the interviews were carried out.

5.1.1 Selection of Cases

The selection of cases was based on each company's involvement in RFID in New Zealand. Although an initial criterion was that the company was not required to have much involvement in RFID for supply chain management, the cases were carefully selected so they exemplified various stages of RFID involvement.

A total of eleven organisations were selected and interviews conducted. The organisations were categorised as follows: four organisations in the supplier/manufacturer category, four organisations in the distributor/logistics service provider category, and three organisations in the retailer category. A fourth retailer could not be contacted.

A balanced approach to the selection of cases within the supply chain category was adopted. In the manufacturer/supplier category, two companies were in the dairy industry, and two from the manufacturing industry. In the distributor/logistics service provider category, one company was a distributor, two were in the transportation industry, and one was in the

engineering service industry. In the retailer category, the three companies represented the apparel, hardware appliance, and household retail sectors, respectively. All these companies have either discussed RFID and/or implemented RFID of some form for supply chain management.

5.1.2 Conduct of Interviews

Prior to the conduct of the unstructured interviews, the participants were asked to answer the 23 questions (Appendix D). The results provided by the participants were reviewed and further unstructured questions were asked to clarify any patterns or trends found. The participants were then asked the questions on the agenda-setting and matching stages (Appendix C). During the interviews, notes and quotations were taken down. They were coded immediately after the interviews. NVivo was used to organise the information into categories or themes. The interviewees were first informed of the background and purpose of the study, and consent (Appendix E) was sought before the commencement of the interview.

Three of the interviews were conducted over the telephone as the participants were located in other cities. Some of the interviewees requested confidentiality regarding their RFID intentions. Thus, for consistency, the interviews were not tape-recorded but were carefully recorded and quotations noted. Two site visits were undertaken as well as a pilot case study – the pilot case study was selected for its active involvement in the RFID community within New Zealand.

5.1.3 Analysis of the Interviews

After each interview, the notes and answers to the questionnaire were coded according to their assigned alphabet described in the interview protocol (Appendix C). The data was uploaded to NVivo for textual analysis. There are two sets of data. The questionnaire's data was used to assess the interviewees' perceptions on the various factors as coded in Appendix D. The interview's data was used in the textual analysis and synthesized with the interviewees' perceptions for an understanding of their perceptions on RFID/SC adoption.

The results of the interviews were analysed by grouping the results into the three supply chain groups, namely, suppliers, distributors, and retailers. Within groups and group-wise comparisons were made. This is discussed in the following sections. The findings are synthesised in Chapter 6 where a model of RFID/SC adoption is presented.

5.2 Introduction to Case Studies

This chapter discusses the case studies analysis by dividing them into two parts. The first part is the within group case analysis. The second part is the cross group case analysis. In both parts, the cases are discussed in suppliers, distributors, and retailers. In the first part, general information about the cases is presented first and then analysed as a group in terms of similarity, difference, and the initiation phase of the Five-Stage Innovation Process (Figure 2-11 in Section 2.5.4.1) in Organisations. A summary concludes each group. The second part follows the same layout but the cases are discussed in cross group.

5.3 Group Case Analysis

5.3.1 Suppliers

5.3.1.1 Suppliers Company Profile

In this category, there are two dairy producers and two manufacturers – one manufacturing baggage cargo systems for airlines and the other manufacturing soft drinks. Table 5-1 shows the summary of the company profiles.

Facts	Company A	Company B	Company C	Company D
Years in operations	> 7	> 70	> 35	> 70
Industry type	Dairy	Dairy	Manufacturing	Manufacturing
Finance turnover (NZ$ mil)	> 10,000	> 250	> 100	> 400
Systems used	ERP, SAP, VoIP	New barcode systems, EDI	MS CRM, VoIP	AS/RS, Voice picking
Current RFID usage/planning*	3	2	1	1
Future RFID usage*	4	4	3	2
Champion (RFID)	IT manager	CFO	No	IT manager
Business case (Yes/No)	No	No	No	No
Have trialed RFID (Yes/No)	Yes	No	No	No
What comes first? (Problem/RFID)	RFID	RFID	Problem	RFID

*Refer to the scale below for the degree of usage

1	2	3	4	5	6	7
Not Extensive			Extensive			Very Extensive

Table 5-1: Summary of Suppliers Profile

Company A is an influential dairy company both regionally and globally. It was founded in the early 2000s with the consolidation of several dairy co-operatives in New Zealand. It now exports dairy products around the world. Due to the extent of its global supply chain,

Company A has been innovative and is an early adopter of technologies. Company A has adopted ERP and several other technologies to align its global businesses situated across different time zones and multiple languages. In terms of RFID, Company A has been involved in RFID events in New Zealand for almost three years. While Company A was actively involved in RFID events, it did not implement RFID citing there was no business case justified for it to adopt RFID. Being a leader in technology, Company A first explored RFID out of interest. A manager was assigned to keep the company informed of the RFID development. The company has since carried out trials by tagging some of its products with RFID labels on individual boxes and pallets. The manager claimed that the trial was satisfactory and gave the company some idea of what RFID can provide. However, the project team concluded that there was no business justification due to the extensive technical issues and the cost of tags for individual item level tagging which the business found as a more logical tagging configuration. The company also suggested that there was no benefit in pushing for the technology. The company believed there was no huge amount of benefit with using RFID and thus there was no compelling reason for it to push for the use of the technology. Nevertheless, the company was keeping a close watch over the technology.

Company B is another large dairy company in New Zealand. It has been in operation for more than seventy years. The company is an independent co-operative with well over 300 farmer shareholders. It manufactures mostly milk-derived food ingredients such as butter, milk powder, and other milk protein products, most of which is exported. With its size, the company claimed to be nimble and effective in communicating with customers. A recent implementation of a barcoding system claimed to have huge cost savings for their operations in terms of inventory traceability. The implementation of the barcoding system is generally seen by some as a logical step to preparing for RFID. Company B is seemed as innovative and

an adopter of technology. In terms of RFID, the company has investigated RFID but preferred barcode mainly due to the ease of implementation and investment cost comparison. As the purpose of the case study is to find out how organisations adopt new technology, the experience Company B has in the implementation of the large scale barcoding system can be studied. Due to the similarity in the context of usage of RFID and the barcode, the experience from barcoding can be related to the adoption of RFID. In terms of implementing barcode, Company B started with a need to address the growing operational capacity in handling increasing stocks. The company decided that scanning was a solution to its labour intensive operations. Using barcodes allowed the company to have a clear view of its stock level from manufacturing to loading of a customer's order. The barcoding system also provided visibility to its aging stocks. With the ability to collect additional information on its stocks, the company believed there was opportunity for business intelligence reporting. The barcoding system's implementation was done with a team of three where the company Finance Director was the champion.

Company C is a manufacturing company in operation in New Zealand for more than 35 years. The company buys materials to build and install baggage and cargo handling systems for airlines around the world. The nature of the customer orders is very much customised and thus there is extensive communication with its customers. The company has two manufacturing plants: one in Dallas, US, and the other in Auckland, New Zealand. In addition, the company has subsidiaries in major regions and several agents, associates and strategic partners in 38 countries worldwide. Its head office is in Auckland. Company C has implemented Microsoft CRM, accounting systems, and other telephony systems such as video conferencing facilities. In terms of RFID, Company C has interest in the technology largely due to a need for traceability of global inventory and the belief that RFID can provide the

solution to identifying inventory stocks. The primary issue with its operation was the lack of information on the wide variety of products the company carried that required maintenance and repair. It took a substantial amount of time and labour to retrieve information of a broken down part that was situated in an airport somewhere in the globe. Company C has spent three years watching the development of RFID particularly in the aerospace industry. It claimed that RFID was still expensive to roll out although it also mentioned that cost was not an issue. There was also no specific requirement from customers or suppliers to adopt RFID. In most cases, the company installed off-the-shelf RFID applications for customers by attaching the RFID readers to the company's built baggage handling systems for tagging luggage. Therefore, there was no need for the adoption of RFID into the company's manufacturing process. In addition, the company was already using barcodes for part identification. The company was struggling to find a business case where RFID was potentially a solution to its traceability difficulty. There was no champion for RFID in the company. Nevertheless, the company was keeping watch on the development of RFID but have no intention unless requested by customers to implement RFID for them.

Company D is another manufacturing company with a state-of-the-art distribution centre in Auckland. The company produces beverages of various kinds. The company has been in operations for almost seventy years in New Zealand. The distribution centre is one of the largest in New Zealand with a fully Automated Storing and Retrieving System (AS/RS). It uses barcoding systems, voice picking technology, and a combination of conveyor systems and telemetry technologies to move pallets of beverages from its manufacturing plant to its distribution centre with little or no human intervention. An improved part of the company's operation is the extension of its automation to the replenishment process. The automated cranes retrieve stored pallets and send them to the loose order picking area as the stocks run

out for picking. In terms of RFID, the company claimed that RFID was not suited for its operations and, in particular, in the FMCG sector. They therefore did not carry out any study on the use of RFID. RFID was only mentioned as a potential technology that the company might consider in future. Similar to Company B, this company was selected as a case due to its implementation of large scale barcoding systems and other supply chain management technologies. The experience the company has in implementing these technologies will provide another perspective to that of the dairy company. Company D has spent three years studying the AS/RS, barcoding systems, and the integration of these technologies into existing systems such as the warehouse management system. The company selected at least three technology suppliers and worked on a trial with the suppliers before deciding on the technology. The selection started with a manageable operation process for the trial and moved on to a larger scale to test the reliability of the technology. A project team of about three members was the typical team size for Company D when working on an IT project. At least a Director will be involved in large projects like the AS/RS and barcoding system. Technology implementation projects are usually driven by the IT department.

5.3.1.2 Suppliers Findings and Analysis

Similarities

When asked about the Readiness of RFID technology and the company and customer infrastructures for RFID adoption, the suppliers group claimed that they are ready for RFID implementation when asked to. This is evident in both the dairy companies where Company A had substantial experience trying the technology while Company B had RFID in its consideration when implementing barcodes. Company A has tested RFID on its butter and cheese product category. It found that the use of RFID was more suited on drier product

categories. As such, the trial allowed the company to define the subject area for RFID in the case of implementation. Although Company C and D did not try out RFID, they both claimed to be in a position to quickly implement the technology. They portrayed to know where RFID could be deployed. The suppliers group also believed that the technology and their customers are ready for the adoption. They agreed that RFID improves supply chain visibility and that there are experienced RFID service providers in New Zealand for an eventual implementation.

Another aspect of RFID the suppliers group unanimously agreed on is the concern for privacy. They believed that with a proper policy, the tracking of items and personal information should not be a major issue. From a business point of view, the technology enables better supply chain visibility and the respondents do not have the intention to associate or misuse the privacy of individuals.

> *"... tracking will become more important."*

In the TOE framework, the suppliers agreed mostly on the environment dimension. For example, the respondents in this group agreed that an RFID system improves the quality of information sharing with customers, there are experienced RFID solution providers, customers are ready to implement RFID, and would implement RFID if customers request them to use RFID. In the dairy industry, it is a requirement by year 2011 to provide information of all dairy products (MAF, 2008). There had been discussion on using RFID for the traceability of products. In 2008, a trial was conducted by the RFID Pathfinder Group in New Zealand using the UHF RFID EPC standards for tracking live stocks (Sundermann & Pugh, 2008). This could explain the attitudes of the respondents from the dairy industry as they are preparing for the likelihood of implementing RFID. They had since conducted trials

or improved their infrastructures in preparing for the implementation of RFID. They also believed that the dairy industry as a whole was gearing up for RFID or traceability of some kind in response to the requirements from the government.

While the suppliers group in general is ready for RFID, they do not have plans in the near future for a full implementation of the RFID systems. However, they indicated that a slight increase in RFID usage is probable. They claimed to have other priority projects over RFID.

> *"Barcodes are more feasible."*

> *"We have a problem but no decision. RFID might not be the answer."*

Company B and D had just implemented full scale barcoding systems and believed that the systems are achieving their desired operating performance. Thus, there was no need for RFID as barcodes were serving them well.

> *"Barcodes are doing well. RFID has no real benefits."*

> *"No study on RFID at the moment ... there is no benefit for FMCG."*

Differences

The suppliers group has differences in their perceptions of the Compatibility and Relative Advantage factors. These differences are better explained by grouping the respondents into the dairy and manufacturing industries. The manufacturers believed that RFID technology is not compatible to a certain extent with theirs and their customers' existing systems. This is

due to the heavy use of machinery in their manufacturing plants that is not configurable or compatible with RFID systems. They were also not convinced that RFID systems benefit their organisations.

> *"Technology [RFID] doesn't fit at the moment; cost is not an issue ... we buy raw material and build and install heavy machinery for our clients. [The manufacturing process is complex]."*

> *"We have state-of-the-art storage and retrieval systems and voice picking ... all fully automated. RFID is only mentioned briefly in our company meeting. What can RFID do to help us [the company]."*

The dairy companies were more convinced that the RFID systems improve data quality and benefit them. They believed that RFID technology is compatible with theirs and their customers' systems. They are also more inclined to yield to pressure to conform to technological and business compliance.

Within the suppliers group there is also a notable theme when it comes to technology trials. Companies with personnel assigned to look at innovation or to champion an innovation are more likely to try new technologies. The champions are like change agents in their company bringing in new technologies to their processes. However, this is subject to prioritisation. The champions are likely to have known RFID first before developing or assessing a need for the use of the technology. These companies are usually more advanced in technology than companies without specific innovation or a change agent role. Examples in the suppliers group are Companies A and D.

Initiation Phase of the Five-Stage Innovation Process

The Five-stage innovation process has two key phases – initiation and implementation. The initiation phase is the main focus of this research. This section highlights the key elements of the initiation phase to identify patterns that may emerge from the cases.

In the first stage of the initiation phase – agenda setting – three of the cases in the suppliers group came to know about RFID first before they explored the potential problems RFID can solve and one case, Company C, experienced some parts tracking issues before they knew about RFID. Company C was faced with parts tracking issues from their manufacturing plants to customer sites. As their production increased, the problems magnified, as one respondent noted.

> *"Company growth and complete change of operational capacity drove the need for better handling of stock".*

This triggered the search for a solution. Although there is a difference in the antecedent events prior to knowing RFID, there is no major difference between Company C and the other cases in the group. There are generally the same perceived attitudes toward RFID by both the manufacturing cases – Company C and D. Due to the technical issues and the lack of business cases with RFID, the companies had prioritised other IT projects over RFID. For example, Company B decided to implement barcode systems, for better traceability of their products, over using RFID due mainly to the lower implementation cost of barcode systems.

> *"Ideally we want to install RFID in the long term but as our Bar Coding system is adequate for the moment, the extra cost of installing RFID is too high for us yet to seriously consider in the short term".*

Other cases chose the more mature or widely adopted technology such as the AS/RS implemented by Company D for high density storage space. Nevertheless, all cases thought there was a need for RFID with their indication of future usage which is higher than their indications of current usage.

In the matching stage, organisations conduct feasibility studies of the technology concerned.

> *"Activities involve choosing a supplier and making decisions on how big the operation would be, and what was in the [specification] for the job".*

The suppliers group matched RFID to mainly traceability, visibility, and automation. In particular, automation was mentioned by all cases. This did not surface in the exploratory survey as a key benefit of RFID due largely to the fact that the questions asked did not indicate automation as a benefit. The cases suggested that automation reduces human errors as a main advantage of RFID over barcode systems.

Of the four cases, only Company A has conducted trials on RFID. A notable pattern is that it took Company A about three months from planning to the trial stage while the other companies had come to know RFID for at least a year.

5.3.1.3 Summary of Suppliers Analysis

In the suppliers group, Readiness and Facilitating Conditions have positive impacts on the future usage of RFID. The cases perceived that RFID allows them to try out various scenarios which allowed them to understand how RFID fits into their organisations. This seems to have a positive relationship with their perceived Readiness. The availability of RFID vendors to support the adoption and the ability to try out various scenarios with RFID have increased their perception of Readiness. The cases claimed to know where they should adopt and not to adopt RFID when asked to do so. Thus they claimed to be ready for RFID adoption. The supplier environmental factors seem to favour RFID adoption as well. For example, they perceived that RFID improves information sharing among supply chain partners and that they will implement RFID when asked to by a key partner. Nevertheless, at the time of the interviews, there were other projects that had higher priority over RFID. Between the dairy and manufacturer groups, Compatibility and Relative Advantage have distinct differences. The manufacturer group has a lower perception on Compatibility and Relative Advantage than the dairy group. Although the manufacturer group sees the benefits of RFID in general, it did not see how RFID can benefit their organisations. The manufacturer group has a sophisticated use of machinery in their manufacturing processes. The group perceived that RFID did not fit with their existing systems and standards. This led to their lower perception on the benefits of RFID to their organisations. Thus, in the supplier cases, the perceived Compatibility seems to have a certain influence on the perceived Relative Advantage. Table 5-2 shows the suppliers' perceptions of the factors.

Factors	TOE Framework	Company A	Company B	Company C	Company D
Compatibility	Technical standards	High	High	High	Low
	Existing processes, values	High	High	High	Low
	Partners' processes, standards	High	High	Low	Low
Relative advantage	Improve data accuracy	High	High	Low	High
	Benefits our organisation	High	High	Low	Low
	Improve information sharing	High	High	Low	High
Pressure	Technology conform	High	High	Low	High
	Organisation requirements	High	High	Low	High
	Important business partners	High	High	High	High
Subjective norm	Knowledge of RFID	High	High	High	Low
	Improve work performance	High	High	High	Low
	Partners think we should use RFID	Low	Low	High	Low
Facilitating conditions	Trialability	High	High	High	Low
	Internal resource, expertise	High	High	High	Low
	Experienced RFID vendors	High	High	High	Low
Readiness	Technical reliability	High	High	High	High
	Organisation infrastructure	High	High	High	Low
	Trading partners	High	Low	High	High
Privacy	Technical aspects	Low	Low	Low	Low
	Company's policy	Low	Low	Low	High
	Partner's policy	Low	Low	Low	Low
	Future RFID usage	Likely	Likely	Likely	Not likely

Table 5-2: Summary of Suppliers Adoption Characteristics

5.3.2 Distributors

5.3.2.1 Distributors Company Profile

In this category, there are one aircraft service provider from the aerospace industry, one fresh produce distributor from the export industry, and two freight movers from the transport industry. Distributors in this research are the intermediary between the suppliers and the retailers. Table 5-3 shows the summary of the company profiles.

Facts	Company E	Company F	Company G	Company H
Years in operations	> 40	> 11	> 20	> 130
Industry type	Engineering	Export	Transport Freight	Transport Freight
Finance turnover (NZ$ mil)	> 4,000	> 1,000	> 150	N.a.
Systems used	Virtualisation, SAP, VMWare	Proprietary WMS	AIS, tracking sys, vehicle booking	EDI, Freight booking
Current RFID usage/planning*	1	3	3	4
Future RFID usage*	4	5	4	6
Champion (RFID)	IT Manager	IT Manager	IT Manager	IT Manager
Business case (Yes/No)	No	Yes	No	Yes
Have trialed RFID (Yes/No)	Yes	Yes	Yes	Yes
What comes first? (Problem/RFID)	RFID	RFID	Problem	RFID

*Refer to the scale below for the degree of usage

1	2	3	4	5	6	7
Not Extensive			Extensive			Very Extensive

Table 5-3: Summary of Distributors Profile

Company E is a major aircraft service provider with presence in New Zealand, Australia, Asia, the Americas, and Europe. The company provides maintenance, repair, and overhaul services to customers in the aerospace industry. With its global network, Company E is using ERP, EDI, and advanced telephony technologies for inventory tracking and status reporting. As major aircraft manufacturers are deploying RFID for parts marking, Company E has been studying RFID since 2003 as a preparation for a possible RFID uptake. The major concern the company had was getting the infrastructure ready for RFID deployment and the readability of the RFID tags especially with products composed mainly of steel. With the company's present out-dated IT infrastructure, it believes that a major overhaul of its infrastructure is necessary, thus making it a major investment both in hardware and software. The company was also planning to take advantage of the RFID capability to introduce other telemetry

technologies for monitoring the life span of its products. Thus, besides RFID, Company E has several other IT projects in a planning stage. The company has a champion for RFID who sees the need to drive the RFID deployment particularly in the aerospace industry. There were a couple of RFID projects in their early planning stage. In the technology aspect, Company E claimed to be one of the first to introduce a full scale vertical implementation of SAP in the aerospace industry and thus is keen to continue that leadership into RFID. The company is following and working closely with the major aircraft manufacturers on RFID. The immediate step to its RFID ambitious is to know how the technology would work in its environment.

Company F is an international fresh fruits exporter. Its head office is in New Zealand with offices in Asia, Europe and North America. The company relies heavily on growers not only in New Zealand but in countries such as, Italy, France, Japan and Korea, to name a few. With a worldwide geographic spread, the company uses a proprietary system to connect disparate growers in its supply chains. Its primary objective is to be able to track and trace its products back to its growers' origins. In terms of RFID, Company F has been investigating RFID since early 2000. The company has a champion who has a keen interest in RFID technology. He has been the main driver of the company's recent development on RFID implementation. Company F has completed a trial on using RFID tagged pallets from a supplier to manage its export operations. This first encounter with RFID was not at all satisfactory. The technology did not provide the reliability the company required. It was at that time expensive to invest full scale in RFID. Given the early days of the development of RFID, the company suggested that its customers and suppliers were not then ready for RFID implementation. Barcodes had at that time been working satisfactorily and thus the implementation of RFID was not necessary. As business grew, it became apparent that the barcoding system was not performing to its expected service levels. One of its suppliers was at the time implementing

RFID within its internal operations. The opportunity came as the RFID tagged products became part of Company F's supply chain. The company took a year to draft a plan and decide on the implementation of RFID in its supply chain. Taking advantage of the RFID tagged shipments from its upstream, Company F started monitoring its staging operations at exporting venues. It believes that in order to gain more benefit out of the implementation, the deployment has to be extended to its offshore counterparts. As this involved other members in its supply chain, the company believes that the deployment overseas was a major issue in the setting up of the infrastructure. The company has three members in its project team and were working closely with external vendors in its proof of concept and subsequent implementation.

Company G is a freight mover specialised in moving containers. It moves more than eight hundred thousand twenty-foot equivalent container units (TEU) per annum. Company G was formed in the late ninety's as a statutory entity. The company uses several advanced IT systems both to manage its operations as well as improve safety. The systems include a vehicle booking system, an automated identification system, and other tracking systems. Its most recent implementation is the use of OCR and some form of RFID in managing trucks reporting to its premises or gate operations. While there is some form of RFID implementation, the use of RFID for tracking containers for supply chain management is still in an investigation stage. The company claimed that there was no agreement with its customers to use RFID and thus it was not an urgent item to do in their agenda. Nevertheless, RFID for supply chain management has been discussed heavily within the company. This is due to the increasing interest by the company's overseas counterparts. The company has been studying RFID for at least three years. Based on its overseas investigation, Company G reported that other governments were facilitating the implementation of RFID through funding and enabling organisations to adopt the technology for efficiency and security

purposes. It suggested that the government in New Zealand should adopt a similar approach to assist New Zealand organisations in technology adoption. It also suggested that RFID would be beneficial when the implementation is across supply chain members – that members collaborate and share the cost of implementation and share the benefits as well. The company will continue to watch the development of RFID particularly in the next two to three years through a business application manager who is also the champion for RFID. Although RFID is potentially an attractive solution to a better supply chain visibility, there are other technologies that the company is exploring as well. The technologies include global positioning systems (GPS) and OCR.

Company H is another freight mover and also a statutory entity. It has been operating in New Zealand for more than a hundred years and was arguably one of the early adopters of RFID. Its RFID system was used primarily for identifying and tracking vehicles. Active tags were used. The RFID system was implemented in replacement of barcodes due to the dirty environment that hindered the readability of barcodes. However, the RFID system is out dated and batteries for most of the active tags have run out. Company H has been exploring new RFID systems, possibly one that was a common standard in the last four years. It depends on the adoption of RFID within the New Zealand trade community. The company has a keen IT manager as the champion of RFID. Similar to Company G, Company H uses RFID primary for asset tracking and safety improvement. It has proposed a couple of business cases and continued to enhance the cases by expanding the use of RFID to cover more of its operations. At the same time, the company is also exploring other technologies to complement its RFID adoption plan. For example, the company found that the inclusion of handheld devices into the process of tracking vehicles with RFID provided a stronger business case. It is also taking

the opportunity to improve its business operations and processes with the introduction of RFID. Company H also has other IT projects to consider apart from RFID.

5.3.2.2 Distributors Findings and Analysis

Similarities

All cases in this group perceived RFID as the potential technology that they should adopt before looking at the solution. They knew about the technology first before looking at potential problems within their organisations that RFID can help to solve. They scored high in terms of Compatibility and Relative Advantage of the use of RFID. They have the opportunity to find and try out RFID systems of various sorts. Their experience with RFID was optimistic and they believed RFID was a potential solution to some of their supply chain issues.

> *"Barcodes are not sufficient. Barcodes are not visible on pallets when stacked up. Labour [of scanning the barcodes is] not accurate, resulting in error input. This is where RFID came in, embedded in pallets to eliminate such errors."*

The key areas for possible deployment are in inventory tracking and operational safety. However, they noted that the time was not right for a full scale RFID implementation. Company G suggested that the adoption would only be beneficial when members of the supply chain utilise the same technology and share the cost of implementation.

> *"There is no agreement from customers to use the [RFID] system."*

The group claimed that their customers are not ready for that yet. From the supply chain perspective, as the intermediary in their supply chains, these cases were more likely to adopt RFID when other members in the same supply chains adopt the same technology standard. It seems that they do not have the incentive to drive the adoption unilaterally.

> *"Containers don't come back to the port often and we rely on shippers for container tagging."*

This is almost similar to cases of the physical infrastructure where all parties share the same transport routes and services. Similarly, an RFID tag that passes through various members in a supply chain is underutilised when not all members adopt the same standard.

> *"Offshore has the same issue of infrastructure. There is a need to set up infrastructure [RFID] in our offshore ports but no ability along the supply chain to achieve this yet."*

As the intermediary and servicing more than one customer, the cases were waiting and watching for their supply chain members to agree on a common standard. While thinking about RFID, the cases have several other IT projects in their work plan and many of these other IT projects that have priority over RFID.

> *"It needs to be aligned with other organisation's priority. Example, weighing bridge [for safety] versus RFID systems."*

Similar with the suppliers group, the distributors were not so concerned with privacy in using RFID. From the business perspective, RFID is just another data collecting technology.

Within the distributors group, it was found that Company G and Company H have the most commonality in their responses to the questionnaires. Both companies are in the same freight moving business. Besides Compatibility, Relative Advantage, and Privacy, both companies had the same sentiment in terms of the Pressure to adopt RFID, their perception on the facilitation of RFID adoption and their Subjective Norms. In terms of the Pressure aspect, both companies would adopt RFID when requested by important business partners.

> *"A driver to the adoption will be a possible mandate from the custom [government] or from big shippers or exporters."*

In the facilitating aspect, they felt they could easily conduct trials on RFID technology with the existing capability and knowledge in their companies and that of external vendors. In the Subjective Norm aspect, they believed that RFID improves work performance and both their decision makers and customers thought their companies should use RFID in the supply chains.

In the TOE framework, the distributors group has more common perceptions on the organisational dimension. For example, they agreed that RFID is compatible with their companies' existing values and beliefs, that RFID benefits their companies and that they should use the technology as they believed they had the expertise to do so. Nevertheless, they thought that their existing infrastructures were not RFID ready.

Differences

The common behaviours of the freight movers group can be distinguished from the other two cases, namely the export and engineering sectors. Firstly, in terms of Subjective Norm, the

freight movers are more inclined to think that their customers and their business decision makers think that they should use RFID in their operations.

> *"Having an end-to-end system gives information to our customers, who are on a separate system, for sharing [information]."*

They are also more inclined to adopt the technology if requested by important business partners. With that perception, the freight movers have taken the initiative to find out more about RFID technology.

> *"...a possible mandate from the custom [government] or from big shippers or exporters ... it is not so much of a competitive advantage, but we like to do more for less and increase our services. We have some conceptual plans for RFID and will take real hard look at RFID and other technologies within two to three years."*

They therefore have tested the technology with various scenarios within their operations. Being able to test and find out more in-depth information about the technology, the freight movers were favourably impressed by the Relative Advantage and Facilitating Condition factors of RFID technology.

> *"We need a quick ROI to get sign-off from our Board within our financial budget. We see the real benefits by using hand-held RFID readers in arranging [cars] for manifest [advance shipping notice] ... and could easily trial RFID with eight different models and adding new features to justify business case."*

This is by no means a conclusion that Subjective Norms result in more positive Relative Advantage and Facilitating Condition factors. It is however, an indication of Subjective Norm as a possible antecedent to information seeking (Pedroso, et al., 2009) that has an impact on the perceptions of Relative Advantage and Facilitating Condition. The exporter, Company F, although it has lower perception in Subjective Norm in the distributors group, is comparatively close to the freight movers in terms of the Relative Advantage and Facilitating Condition factors. This may be due to a personal interest in RFID of the RFID champion. He has a good knowledge of the technology and is a believer that RFID performs better than barcodes in operational efficiency.

> *"Customers are not ready, supply chain is not ready ... the impacts [of using RFID] will be more supply chain information than before and improvement to our recall process to specific batch."*

The company, taking advantage of the upstream usage of RFID, has implemented RFID within its local operations under his watchful eyes. Thus, personal interest of an innovation champion in an organisation may also lead to information seeking about the technology.

Initiation Phase of the Five-Stage Innovation Process

In the agenda setting stage, all cases in the distribution group came to know about RFID first before assessing how the technology could help to solve their problems. With the awareness of RFID technology, the cases gathered information within their industry. There is little or no observable evidence that they have attended or participated in any form of RFID seminar locally. The only exception is Company F as they took advantage of their upstream supply chain partner use of RFID to try out the technology within their operations. They used the

same RFID consultant as a source of information. In this stage, it is also evident that the cases are prioritising projects as well as evaluating the development of RFID that facilitates the adoption. The factors they are concerned with are primarily technological and environmental. There are factors that are beyond their control. For example, Company E claimed that RFID is not reliable due to the metal components of the products in their supply chain. The freight movers expressed their concerns of the standards to be adopted by their upstream supply chain partners. Thus the factors within the technological and environmental dimensions are potentially impediments to RFID adoption in the distributors group.

> *"Barcode already exists. The [technical] issue is with the change to the whole infrastructure not the cost of tags."*

> *"Industry needs to get together to implement RFID for benefits."*

In the matching stage, the distributors group assessed the compatibility of RFID more against the environment where they operate. Companies E and F suggested that RFID did not work so well with their product. The products are high in metal and liquid content in the respective companies. These elements affect the readability of the tag and thus the accuracy of the read rate. The freight movers were primarily concerned about asset tracking especially when it was outside of their jurisdiction. There was also a need to match the technology with the environmental factors. The distributors group acknowledged that the adoption of RFID depends on the partners in a supply chain using a single standard. They suggested that mandating would be a way to bring organisations to collaborate on the use of a single standard.

5.3.2.3 Summary of Distributors Analysis

In the distributors group, it seems that dependency on their upstream supply chain partners has impact on future usage of RFID. They did not indicate an increase in future usage of RFID but taking a wait-and-see strategy relative to their upstream supply chain partners. The freight movers, although having higher positive perceived Compatibility, Relative Advantage, Facilitating Condition, and Subjective Norm, did not indicate any increase in future usage. Their primary concern was the standards to be used by their supply chain partners. Similar to the suppliers group, the perceived Facilitating Conditions of RFID impacts the perceptions of Readiness for the distributors group. Overall, the distributors group thought that their organisations were capable of and ready for RFID adoption. However, they are dependent on their upstream supply chain members and their environmental factors. It is worth noting that in the case of Company E, where they perceived a likelihood of mandate in the aerospace industry to use RFID for traceability, they have indicated an increase in future usage. In the case of Company F, personal interest seems to drive the development of the RFID business case. Company F is also an example of how the use of RFID by an upstream supply chain partner facilitates the adoption. Table 5-4 shows the distributors' perceptions of the factors.

Factors	TOE Framework	Company E	Company F	Company G	Company H
Compatibility	Technical standards	High	High	High	High
	Existing processes, values	High	High	High	High
	Partners' processes, standards	High	High	High	High
Relative advantage	Improve data accuracy	High	High	High	High
	Benefits our organisation	High	High	High	High
	Improve information sharing	High	High	High	High
Pressure	Technology conform	High	Low	Low	High
	Organisation requirements	High	High	High	High
	Important business partners	High	High	High	High
Subjective norm	Knowledge of RFID	High	High	High	High
	Improve work performance	High	Low	High	High
	Partners think we should use RFID	Low	Low	Low	High
Facilitating conditions	Trialability	High	High	High	High
	Internal resource, expertise	High	High	High	High
	Experienced RFID vendors	High	High	High	High
Readiness	Technical reliability	Low	High	High	High
	Organisation infrastructure	Low	High	High	Low
	Trading partners	Low	High	Low	High
Privacy	Technical aspects	Low	Low	Low	Low
	Company's policy	Low	Low	Low	Low
	Partner's policy	Low	Low	Low	Low
	Future RFID usage	Likely	Very likely	Likely	Very likely

Table 5-4: Summary of Distributors Adoption Characteristics

5.3.3 Retailers

5.3.3.1 Retailers Company Profile

In this category, there are three retail companies covering the apparel, hardware appliances, and household retail sectors. All three companies are reasonably large in terms of their total number of store outlets; one of which is a conglomerate with franchises in New Zealand. Table 5-5 shows the summary of the company profiles.

Facts	Company I	Company J	Company K
Years in operations	> 90	> 100	> 25
Industry type	Retail	Retail	Retail
Finance turnover (NZ$ mil)	N.a.	> 50	> 1,500
Systems used	SAP, Business Ware, Biztalk	POS, EDI	Business intelligence, in-house ICT
Current RFID usage/planning*	1	1	2
Future RFID usage*	1	2	3
Champion (RFID)	CFO	No	IT Manager
Business case (Yes/No)	No	No	No
Have trialed RFID (Yes/No)	No	No	Yes
What comes first? (Problem/RFID)	RFID	RFID	RFID

*Refer to the scale below for the degree of usage

1	2	3	4	5	6	7
Not Extensive			Extensive			Very Extensive

Table 5-5: Summary of Retailers Profile

Company I is primarily a fashion department store with over fifty stores nationwide. Its stocks include homewares, manchester, appliances, electronics, furniture and beddings. It has been in operation in New Zealand for almost one hundred years. The company uses multiple IT applications from ERP to warehouse optimisation. It was upgrading its IT infrastructure to use an IP-based Wide Area Network (WAN), wireless networks and virtual back-end systems. The company has just completed the implementation of a new Point of Sale (POS) system and hardware in all stores. The company is committed to improving its operational efficiency through better deployment of IT infrastructure and applications. In terms of RFID, the company started exploring RFID four years ago in consultation with a multi-national IT corporation. After much study, Company I claimed that the retail industry as a whole is not ready for RFID tagging. With other more immediate solutions to be implemented, Company I

was putting RFID on hold with someone within the company watching the development of RFID in the retail space. There was however no champion identified specifically for RFID. The primary reasons for concluding that the retail industry was not ready for RFID are the cost of tags and the lack of support or facilitating incentives. The company concluded that tagging on individual items is not feasible with the cost of the tags affecting its operating costs. It would only make sense to tag on big ticket or expensive items. The company felt there was no incentive to lead in RFID or invest in RFID where there were still a lot of unknown factors about the implementation of the technology. The company did not have the knowledge or expertise required. It claimed to be waiting for RFID to further mature before looking into the possibility of using it in its operations. In the meantime, the company is investing in optimising its cross docking operations through automation and sorting systems as the immediate priority.

Company J is a franchise conglomerate with a wide range of department retail stores from sport apparel to outdoor activities products and household furniture to hardware home improvement products. Company J operates mainly in the South Island of New Zealand since the 1900s. The company has just upgraded its POS system with enhanced electronic transfer and replenishment features. With its diverse product range and business models, Company J is using technology to improve its supply chain operations. In terms of RFID, the company believed that with the use of RFID for tracking cases, it was hoping to improve its stock-take accuracy, security, and speed up order processing. It had planned to integrate the use of RFID with its newly upgraded POS system and key suppliers. However, the company realised that it would require a massive change to its current infrastructure. Without the expertise, the company is holding back on the adoption. Given that a majority of Company J's businesses are franchised from other leading retail traders, the company depends on their suppliers when

it comes to technology adoption for supply chain management. Therefore, the company had only worked out the timeframe to be ready for RFID and had decided not to lead in this area. It justified that its suppliers were not ready and there was no capability at this moment to roll out RFID for supply chain management. Similarly, Company J has no champion for RFID but its chief executive is overseeing the development of RFID in New Zealand.

Company K is another prominent department store in New Zealand. It is one of New Zealand's largest general merchandise retailers with 85 stores nationwide. Its product range includes apparel, entertainment and technology, music, sporting, gardening, grocery, jewellery stationery and toys. The company had been spending on upgrading its IT infrastructure over the last three years. With the IT infrastructure upgraded, the company has moved its focus to improving its in-store service including labour management in stores, increasing purchasing efficiency, and product range management. To achieve these, the company has been exploring technology such as RFID for automatic data capturing in order placement, product receipt, and stock replenishment. Company K has been an early adopter when it comes to technology adoption. It has appointed a champion for RFID and has been conducting RFID trials on several product ranges with systems integrators in the last four years. The trials were mainly in-store and not intended for its supply chain management. Already there were several scenarios in which the company would like to make use of RFID. One such scenario is to use the in-store location information of the apparel items for direct marketing, such as marking down the retail price for specific items, and the item bundling. The company took a year to study the technology before it decided to conduct the trials. Although there were no technical issues during the trial, the company decided to cease the implementation for cost reasons. It believed that it was not cost efficient to tag at the item level with the current price of an RFID tag. Without further trial on a larger scale, the

company was not sure about the technical issues if it was to roll out RFID. It claimed that its IT infrastructure and suppliers were both not ready for the adoption. Nevertheless, the company is still keen on RFID and continues to watch the development of RFID in the retail space believing the possible compliance requirement to adopt RFID is for food and drugs traceability. It has also pointed out that there were other projects planned in the next twelve months.

5.3.3.2 Retailers Findings and Analysis

Similarities

Similar with the distributors group, the retailers group came to know RFID before looking at problem areas where RFID could be employed. They had spent some time studying the technology upon hearing of Wal-mart's and Metro's RFID mandates. They found there was no need for their business to use RFID and there was also no interest from other parts of their supply chain.

> *"Four years ago engaged a consultant to investigate RFID … no trial was needed as there was no need for RFID at that stage."*

They also made the remark about their suppliers not having the capability to adopt RFID. Thus there was no economy of scale to introduce the technology at the time where RFID was yet to be a mature technology.

> *"Suppliers are not capable of implementing [RFID] and there is no scale in the supply."*

The retailers also admitted that they did not have the expertise or know-how to use RFID in their operations. Only Company K has tested RFID extensively.

The group agreed unanimously on the Relative Advantage of RFID. They believe that RFID improves data accuracy and information sharing, and it would benefit their companies. As with the other two groups, the retailers group was not so concerned with the privacy issue of using RFID. One of the respondents noted that privacy may be a concern but it was just not at the top of their concerns list.

> *"Privacy would be an issue and not a concern at this stage. There are other priorities."*

In the TOE framework, the retailers group has many common perceptions on the environment dimension. They share common perceptions regarding what they thought of their customers and suppliers. For example, the retailers agreed that using RFID improves the quality of information sharing with their customers and suppliers, and they could use the technology. However, they perceived that their customers and suppliers are not ready for the use of RFID.

> *"RFID in transportation of cases allows electronic manifest [for improved information sharing] ... there is no interest from customers"*

All three cases have just upgraded their IT infrastructure, mainly, their point-of-sale systems. They are next focusing on improving their in-store efficiency and warehouse cross dock operations. Thus, they had other projects in their work plan and RFID was not their immediate priority project. Nevertheless, they are watching the development of RFID closely.

> *"Wait for RFID to mature ... someone is observing RFID development [at the top management level]."*

Differences

Company K having tested the technology was confident with the performance of the technology. The trials allowed the company to understand how the technology should work and the benefits it could yield. The company found that tagging on smaller high value products was more practical.

> *"... more benefits on item tracking such as DVDs and CDs."*

However, the other two companies claimed the technology was not proven and it was expensive to introduce RFID tags where most of their products were of low value. One of them noted,

> *"New technology is not always what it is actually like."*

When asked about the facilitating factors, the group did not agree that RFID can be easily tried out. While Company K has tested the technology and was satisfied with the results, Company J claimed there was no expertise to test the technology and suggested the tagging of RFID should be at the source or upstream of the supply chain.

> *"Source marking will see more benefits ... but there is no capability at the moment therefore no trials."*

In terms of Pressure, Company K claimed that the company would not use RFID if requested by important business partners while Company I and Company J both indicated they would use RFID if requested by important business partners. This seems to suggest that the more confident an organisation is with the technology – that is having tested and satisfied with what the technology can do – the less likely it will give in to pressure from business partners. An explanation would be that the organisation after testing the technology knows what to do and where to deploy the technology that best yields the returns. The organisation thus would not simply adopt the technology if it thinks the technology is not suitable for its operation even though asked by a customer or supplier.

> *"Need to plan for 'space'; there are other priorities and planning takes at least 12 months."*

In general, the group differs in their technology dimension. It was interesting to note that while Company J disagreed that RFID was compatible with its existing systems, it believed the technology can be tested out with various scenarios and the technology was reliable for implementation. However, Company I, who agreed that RFID was compatible with its existing systems, disagreed the technology allowed testing at various scenarios and suggested that the technology was not reliable yet for implementation. There is clearly misinformation between the two companies. As for Company K, it has tested and was satisfied with the results, however, it still claimed that the technology was still not reliable for implementation. The company responded that its trials were limited to a few scenarios and were concerned with the technical issues if implementing at a larger scale.

"There was no major issue with RFID but the applicability of it for a business case [is not there]. Trials were conducted mainly on in-store replenishment and not so much on supply chain management."

Initiation Phase of the Five-Stage Innovation Process

In the agenda setting stage, the retailers came to know about RFID first. Nevertheless, they were not actively involved in seeking information about RFID except for Company K where trials were conducted in-house with a consultant. According to Company I and J, RFID is not compatible or easily tested in a retail environment. They thought that RFID is not a proven technology and did not want to be leaders in adopting the technology. They have other priorities that are more visible and feasible to implement than RFID systems.

"There is no business case for us, only worked out viable timeframe to be ready not to lead the market [in RFID adoption]."

"No gain in trying to lead the market."

"Is it [RFID] a leading edge or bleeding edge?"

In contrast, Company K has an RFID champion driving the feasibility study of RFID. He put together a small team to set an RFID test laboratory to carry out tests. Company K has spent a lot of time studying and understanding the technology.

"We spent a lot of time reading and attending about RFID – still stands; we want to be leading [in RFID adoption]."

In the matching stage, Company I and J which have not done trials on RFID claimed that RFID could potentially be implemented for stock taking, security, and improving delivery accuracy. They perceived that the Facilitating Conditions are not in favour of RFID adoption.

> *"Facilitating is not favourable. Wait for RFID to mature. We only know what we know, but there is a lot more that we may not know."*

Company K who has done trials on RFID was able to provide more specific areas in which RFID can yield benefits for their company including performance measurement. They believed that the visibility of products enabled by RFID can potentially improve pricing strategies for seasonal and perishable products. Company K found some business cases – simplified processes, labour diverted to servicing and selling, and sales increased through better availability and stock accuracy.

> *"Readers on rackings need to be set up, tag [location] on carton boxes, various items were tested. We could implement [real-time] discount for seasonal items with RFID and therefore less mark down and more profitability."*

5.3.3.3 Summary of Retailers Analysis

In the retailers group, Relative Advantage is perhaps the only factor that is positively perceived. The cases perceived RFID as useful and beneficial to their organisations. However, they did not high positive perceptions of the Compatibility, Facilitating Condition, and Readiness. The retailers believed that they did not have the expertise and there were no

qualified vendors to assist in the adoption. They also believed that their customers and suppliers were not ready. In general, their environmental factors were not favourable for RFID adoption. Companies I and J who did not do trials on RFID have mixed perceptions of Compatibility and Facilitating Condition. This could be due to the information they received from their sources. It is also noted that the two companies are more inclined to adopt RFID if asked by key trading partners. Company K in contrast is less likely to adopt RFID if requested by an important business partner. This is explained by that fact the Company K has extensively tested RFID and is well positioned to know what type of RFID configurations suited its operations. Thus, Company K is less likely to simply adopt RFID when requested by a customer or supplier. In fact, Company K maintained that RFID was still not reliable for a large scale implementation. The retailers group also believed that RFID improves the sharing of information if it is implemented across supply chains. Since that their customers and suppliers were not ready for the adoption, there was no economy of scale to introduce the technology to their supply chains. As such, there is not a business case to pursue RFID further. The retailers revealed that they had other IT and non IT projects that they were already working on, such as cross-dock operations, automation, sorting systems, POS upgrading, and improving replenishment. Table 5-6 shows the retailers' perceptions of the factors.

Factors	TOE Framework	Company I	Company J	Company K
Compatibility	Technical standards	Low	Low	High
	Existing processes, values	High	High	High
	Partners' processes, standards	Low	Low	Low
Relative advantage	Improve data accuracy	High	High	High
	Benefits our organisation	High	High	High
	Improve information sharing	High	High	High
Pressure	Technology conform	High	Low	Low
	Organisation requirements	High	High	Low
	Important business partners	High	High	Low
Subjective norm	Knowledge of RFID	High	High	High
	Improve work performance	High	High	High
	Partners think we should use RFID	Low	Low	Low
Facilitating conditions	Trialability	Low	High	High
	Internal resource, expertise	Low	Low	Low
	Experienced RFID vendors	Low	High	Low
Readiness	Technical reliability	Low	High	High
	Organisation infrastructure	High	Low	High
	Trading partners	Low	Low	High
Privacy	Technical aspects	Low	High	Low
	Company's policy	Low	Low	Low
	Partner's policy	Low	Low	High
	Future RFID usage	Not likely	Not likely	Likely

Table 5-6: Summary of Retailers Adoption Characteristics

5.4 Cross Group Case Analysis

In this section, a cross group case comparison is discussed. The aim is to identify patterns among the three groups: suppliers, distributors, and retailers. The key attributes of each group are summarised below. It is followed by the group comparison. Both the findings from the within and cross groups analyses are then further investigated. Findings are then analysed and supported with evidence from the cases and the literature review.

Suppliers

Within the suppliers group, perceived Readiness and Facilitating Condition are two main common factors that are positively related to RFID adoption. The cases believed that RFID is reliable and useful in the sharing of information among their supply chain partners. They had a positive attitude towards their external factors – environmental aspects of RFID adoption. For example, they were willing to adopt RFID if and when asked by their key supply chain partners. However, they mentioned that they had other priority projects in their plans over the next couple of years. The suppliers group was also positive towards their existing privacy policy and had no concern over privacy issues.

There are differences between the manufacturer and dairy groups. The manufacturer group has lower perception of Compatibility and Relative Advantage than the dairy group. It is found that the amount of existing machinery in use might have a negative impact on the two factors. The manufacturer group claimed that the integration of RFID with existing systems was a complex task that required extensive knowledge and expertise in RFID systems. Another explanation is the requirement to trace animal and dairy products by year 2011 as directed by the Ministry of Agriculture and Forestry. This is a motivating factor for the dairy companies to implement some sort of a scanning system. RFID is the forerunner as the scanning technology that the dairy industry would choose to adopt to comply with the requirement.

In terms of the other aspects of the company's characteristics, Company A with an IT manager as the champion for RFID had done some trials on RFID. The other two companies with champions, although they did not do RFID trials, had implemented large scale barcoding systems and some form of process automation. Both these companies had at least a director

level person in charge of projects including IT. In the case of Company B, it was the CFO who was the main sponsor of IT projects. The fourth company, which didn't have a champion, did not conduct any RFID trials at all.

Distributors

The distributors group in general displayed a dependency attitude upon its upstream supply chain partners for the adoption of RFID. They had high perceptions of Compatibility and Relative Advantage. Overall they perceived the organisational dimension highly which suggests that they were more confident of their organisations' readiness, skills, and facilitations than in technological and environmental dimensions. They were, however, cautious about what RFID standards and applications to adopt as they served multiple suppliers and retailers. This is particularly evident in the two freight movers. The distributors group also perceived that their customers were not ready including their suppliers. The distributors group also indicated they had other projects in the pipeline and RFID was only one of the many projects.

An obvious difference within the distributors group is the higher scores of the freight movers as compared against the exporter and engineering sectors. The freight movers consistently perceived Compatibility, Relative Advantage, Facilitating Condition, and Subjective Norm highly. This could be explained by the organisation process and value theory. The freight movers' processes are primarily in the logistics or supply chain areas. They own and operate logistics assets while the other two sectors' processes did not involve an extensive supply chain ownership. The freight industry has been involved in RFID usage for some time in the container and the rail car tracking areas. Their systems and processes might be more accustomed to the use of RFID systems.

There is a clear difference in the perceived Readiness of their customers and suppliers within the distributors group. The freight movers are split in their perceptions of their customers' and suppliers' readiness and so are the exporter and engineering companies. This is obvious in that the group that believed their customers and suppliers were ready had been involved in RFID – Company F was implementing RFID because its upstream was implementing it and Company H had been using old RFID systems in tracking rail cars. Companies E and G, although were positive in other aspects, were not involved in RFID with suppliers or customers and, thus, perceived that their customers and suppliers were not ready. They foresaw that the adoption would not happen in the near future but estimated that there would be an increase in the uptake of RFID if the technology was cheaper. Company G suggested that it would be another three years before RFID becomes a mainstream technology. In the aerospace industry, Company E foresaw that uptake would start when the tracking and security of items becomes mandatory.

In terms of the other aspects of the company's characteristics, all three companies with a champion for RFID had done some various forms of RFID trials and come to know RFID before assessing the problem areas RFID could be employed in. The only company that did not conduct trials on RFID did not have a champion for the technology. The company came to know about RFID as it was looking for a solution to a problem.

Retailers

The retailers group agrees generally in the environmental dimension of RFID adoption. They perceived there was no experienced RFID service provider in New Zealand, RFID improved quality of information sharing, their customers were not interested in RFID, and their

suppliers were not ready for RFID. The retailers were also not concerned about privacy issues.

The retailers group in general has mixed information about what RFID can do. They had different opinions on the technical aspects of RFID. Company J believed RFID could be easily tested with various scenarios and that RFID was reliable but suggested that RFID was not compatible with their existing systems. Company I disagreed that RFID could be tested with various scenarios and that it was reliable but agreed that RFID was compatible with their existing systems. A closer look at their evaluations suggested that both companies were in fact observing the same areas where RFID could potentially be implemented. They suggested stock take, security, and stock availability as three main areas where RFID was the preferred candidate for improvement. In terms of their current initiatives, they were focusing on warehouse and store front operations. Their objectives then were to improve product movement from their distribution centres to the store outlets as well as to integrate their point of sales systems with their suppliers. These two companies were also more inclined to succumb to pressure if asked to adopt RFID while Company K who had done some RFID trials extensively was less likely to adopt RFID when asked.

In terms of the other aspects of the company's characteristics, Company K, which had an RFID champion, has conducted trials on RFID while the other two without champions had not done any RFID trials.

5.4.1 Cross Group Case Findings and Analysis

Similarities

The profile shown in Table 5-7 suggests that the cases are reasonably similar or close in terms of the operational, financial, and technological aspects. All groups indicate an increase in future usage intention with the distributors group having a much higher increase from current usage. The systems in use were sophisticated and integrated. Most of the cases reported that they knew RFID first before looking at their problems which could be potentially solved with RFID.

Facts	Supplier	Distributor	Retailer
Years in operations	> 45	> 50	> 70
Industry type	Dairy, Manufacturing	Engineering, Export, Transport	Retail
Finance turnover (NZ$ mil)	> 3,000	> 1,500	> 1,000
Systems used	ERP, SAP, VoIP, MS CRM, AS/RS, Voice picking, barcoding sys	Virtualisation, SAP, VMWare, AIS, Ship tracking systems, Vehicle/Freight booking, EDI	SAP, Business Ware, Biztalk, POS, EDI, in-house ICT
Current RFID usage/planning*	2	3	1
Future RFID usage*	3	5	2
Champion (RFID)	Mostly Yes	Mostly Yes	Mostly No
Business case (Yes/No)	No	Neutral	No
Have trialed RFID (Yes/No)	Mostly No	Mostly Yes	Mostly No
What comes first? (Problem/RFID)	Mostly RFID	Mostly RFID	RFID

*Refer to the scale below for the degree of usage

1	2	3	4	5	6	7
Not Extensive			Extensive			Very Extensive

Table 5-7: Supply Chain Group Profile

Perhaps the only obvious similarity in terms of the factors is the groups' perceptions of Privacy. They strongly believed that privacy should not be a concern to business since the

information collected is primarily about their supply chain operations. They suggested that they had security measures and privacy policies within their organisations to safeguard personal information. They noted that privacy was just not on top of their concerns list.

Differences

The group profiles shown in Table 5-7 depict the various characteristics of the three supply chain groups. Most of the members of the suppliers group had a champion for RFID, they knew of RFID but did not do trials on RFID and reported no business case for using RFID.

> *"Technology [RFID] doesn't fit at the moment; cost is not an issue ... we buy raw material and build and install heavy machinery for our clients. [The manufacturing process is complex]."*

> *"We have state-of-the-art storage and retrieval systems and voice picking ... all fully automated. RFID is only mentioned briefly in our company meeting. What can RFID do to help us [the company]?"*

Most of the members of the distributors group had a champion for RFID, they knew of RFID first, had done some trials on RFID but were split in their reported business cases.

> *"Containers don't come back to the port often and we rely on shippers for container tagging."*

"Customers are not ready, supply chain is not ready ... the impacts [of using RFID] will be more supply chain information than before and improvement to our recall process to specific batches."

"We need a quick ROI to get sign-off from our Board within our financial budget. We see the real benefits by using hand-held RFID readers in arranging [cars] for manifest [advance shipping notice] ... and could easily trial RFID with eight different models and adding new features to justify a business case."

"... a possible mandate from Customs? [government] or from big shippers or exporters ... it is not so much of a competitive advantage, but we like to do more for less and increase our services. We have some conceptual plans for RFID and will take a real hard look at RFID and other technologies within two to three years."

The retailers group, in contrast, mostly did not have a champion; they knew about RFID but had not done trials on RFID, and they reported no business cases either.

"Suppliers are not capable of implementing [RFID] and there is no scale in the supply."

"Wait for RFID to mature ... someone is observing RFID development [at the top management level]."

"There was no major issue with RFID but the applicability of it for a business case [is not there]. Trials were conducted mainly on in-store replenishment and not so much on supply chain management."

This simple categorisation shows that the distributors are leading in trialling of RFID and, possibly, in adoption given that some of the distributors had already identified business cases for use of RFID. The suppliers are the second most likely group to adopt RFID. This is supported by the findings of their reported likelihood of adopting the technology if asked by their key business partners. However, the retailers had a mixed understanding of RFID, especially in terms of technical compatibility. Their pessimistic perception of Facilitating Condition and Readiness may deter their adoption of the technology. Thus, retailers are the least likely group to adopt RFID in New Zealand.

In general, the suppliers and retailers rate Compatibility and Relative Advantage lower than the distributors and are more likely to adopt RFID if asked by their key business partners. While the suppliers had a positive perception of their external trading partners, the distributors and retailers were more pessimistic about their trading environments, and especially their suppliers.

"Offshore has the same issue of infrastructure. There is a need to set up infrastructure [RFID] in our offshore ports but no ability along the supply chain to achieve this yet."

"There is no agreement from customers [suppliers] to use the [RFID] system."

> *"Suppliers are not capable of implementing [RFID] and there is no scale in the supply."*

Initiation Phase of the Five-Stage Innovation Process in Organisations

In the agenda setting stage, most of the cases came to know RFID before identifying suitable problems except Companies C and G. Company C explored RFID as they had the need to solve their product tracking issues. They had been studying RFID for a while but did not conduct any trial. Company G had long been looking for a solution to their logistical issues. They believed that RFID was only a part of the solutions and they were looking out for other technologies at the same time.

> *"For benefits, couple RFID with OCR [optical character recognition] to identify containers for reporting at the gates, and to direct drivers and notify the office of the arrivals."*

They had conducted trials on RFID within their operations areas. They reported, after the interview for this research, that they were investigating the possibility of using RFID together with OCR to improve security and tracking performance. Therefore, the notion of recognising the problem or the technology first, does not suggest any significant impact on technology adoption. It does, however, draws attention to the process of how information about the technology is being processed by organisations. This is supported by the analysis of the suppliers group where there is little difference between Company C and the rest of the suppliers in their perceived attitudes towards RFID. The retailers – apart from Company K – were not actively involved in information seeking. They, however, perceived that the technology was not ready for adoption and that it was not compatible with their systems.

> *"Four years ago we engaged a consultant to investigate RFID … no trial was needed as there was no need for RFID at that stage."*

Given that these organisations did not carry out trials, one can safely argue that the lack of information on and the preconceptions of a technology could lead to a lower adoption rate. Lacking information, an organisation could form an unfavourable opinion of the Facilitating Condition and Readiness that would otherwise support the technology adoption. The retailers in this study had lower scores for Facilitating Condition and Readiness, while the distributors and suppliers seemed to have more activities related to RFID, but the suppliers stopped short of conducting any RFID trials.

In the matching stage, the cases seemed to evaluate adoption more against the environment in which they operate and in relation to the readiness of their supply chain partners. A few respondents had done some trials on RFID within their own operations areas but had found no business case to justify further investment in RFID. Company H suggested that they were able to justify the investment only by expanding the implementation beyond their stages of the supply chain. In doing so, they were able to make reductions in operations inefficiency and, as a result, end up with a better cost/benefit model. Some of the cases also reported that they were waiting until their supply chain partners had adopted RFID. This suggests that they were aware of RFID systems requiring the collaboration or participation of supply chain members to implement the technology meaningfully. Mandating is a motivation that might push these members to adopt RFID. Table 5-8 shows the supply chain groups' perceptions of the factors.

Factors	TOE Framework	Supplier	Distributor	Retailer
Compatibility	Technical standards	High	High	Low
	Existing processes, values	High	High	High
	Partners' processes, standards	High	High	Low
Relative advantage	Improve data accuracy	High	High	High
	Benefits our organisation	Low	High	High
	Improve information sharing	High	High	High
Pressure	Technology conform	High	Low	Low
	Organisation requirements	High	High	High
	Important business partners	High	High	High
Subjective norm	Knowledge of RFID	High	High	High
	Improve work performance	High	High	High
	Partners think we should use RFID	Low	Low	Low
Facilitating conditions	Trialability	High	High	High
	Internal resource, expertise	High	High	Low
	Experienced RFID vendors	High	High	Low
Readiness	Technical reliability	High	High	Low
	Organisation infrastructure	High	High	High
	Trading partners	Low	Low	Low
Privacy	Technical aspects	Low	Low	Low
	Company's policy	Low	Low	Low
	Partner's policy	Low	Low	High
	Future RFID usage	Likely	Very Likely	Not likely

Table 5-8: Summary of Supply Chain Group Adoption Characteristics

5.4.1.1 Summary of Cross Group Case Analysis

Overall, the cases perceived RFID as useful and beneficial to their businesses. However, the retailers did not perceive highly in Facilitating Condition and Readiness. The suppliers and distributors perceived well in the Compatibility, Facilitating Condition, and Readiness categories, with a few exceptions in Compatibility. Both the suppliers and distributors are more likely to adopt RFID than the retailers. In general, the suppliers are ready to adopt RFID and believed that their environments will facilitate the adoption. The distributors were ready

but believed that their customers and suppliers were not ready to adopt RFID. The retailers were not ready as they believed that RFID and their suppliers were not capable or ready for adoption yet.

The question of what comes first – recognising a problem or knowing RFID – did not reach a conclusion that is supported by this research. There is little evidence that knowing RFID first leads to the likelihood of RFID adoption. There is also little evidence to support the 'identified problem first' argument. However, there is some evidence that the 'knowing RFID first' argument has, to some extent, effects on other factors. The cross group case analysis however did find some evidence in the notion of a champion as a key aspect of driving adoption. The group with no champions did not do trials on RFID while the group with champions had done some RFID trials. A counter argument will be that an organisation will appoint a champion if they decide on an RFID trial. While it may prove to be correct in the case of no trial and therefore no champion, the counter argument does not explain the likelihood of an adoption if there is a champion. For example in this research, there are eight cases with champions and in two out of the eight cases trials did not take place. Of the six cases that have done trials on RFID, five of the champions had permanent positions in either innovation or IT. Three of them reported to have interest in RFID. The two that did not do trials on RFID were in one case a CFO and in the second case a member of an organisation in which the adoption decision was made offshore. Therefore, there is evidence to support that organisations are more likely to conduct trials on RFID when they have an IT or an innovation manager as a champion and when they have local authority to make the adoption decision.

5.5 Summary

The suppliers perceived that Readiness and Facilitating Conditions are positively related to RFID adoption. They believed the RFID technology is reliable and useful in the sharing of information among their supply chain partners. The manufacturer group has lower perception of Compatibility and Relative Advantage than the dairy group. The manufacturer group claimed that the integration of RFID with existing systems was a complex task that required extensive knowledge and expertise in RFID systems. In contrast, the dairy group is faced with a possible mandate to adopt RFID for tracking farm animals, hence, they have to be ready for the mandate.

The distributors had more confidence of their organisation's readiness and skills than their environment. The distributors had mostly done some form of RFID trials, hence, they were confident of their ability to implement RFID should they have to. It is found that they perceived that their suppliers or customers were not ready for RFID/SC adoption.

The retailers were the least prepared among the three supply chain categories. They perceived there was no expertise in New Zealand to implement RFID. The retailers group in general has mixed information about what RFID can do. They had different opinions on the technical aspects of RFID.

The next chapter discusses in detail the findings of the case study.

CHAPTER 6 – DISCUSSION

6.1 Research Findings

In Chapter 5, textual analysis was conducted on the interviews data. By putting together the textual analysis and the responses to the interview questionnaire, the findings were synthesized and themes developed. This chapter discusses the developed themes, formed around the seven requirements used in the questionnaire. Table 6-1 shows the meaningful themes and factors found when describing RFID/SC adoption.

Findings and Themes	Impact
Finding 1: Compatibility, Readiness, and the Facilitating Condition are important factors in the evaluation of technology for adoption	High
Finding 2: The Facilitating Condition has some effects on Readiness	Medium
Finding 3: The Complexity of systems integration has some effects on Compatibility	Medium
Finding 4: Compatibility and Relative Advantage are associated with one another	Medium
Finding 5: The Subjective Norm has some effects on the level of engagement in information seeking about a technology	Medium
Finding 6: Dependency on trading partners has some effects on technology adoption	High
Finding 7: The Subjective Norm may become an important factor in technology adoption when Dependency on trading partners is high	Low
Finding 8: Relative Advantage is less important than Compatibility but is a motivational factor that has some effects on the adoption of technology at the organisational level	Low
Finding 9: Subjective Norm and Information Process are associated with one another	Low
Finding 10: Organisations with a champion for IT adoption are more likely to adopt the technology than organisations without a champion for IT adoption	Low
Finding 11: IT projects are prioritised based on budget allocated and their value to the organisation's strategy	Low
Finding 12: Knowing the technology first results in a positive evaluation of the technology and how it improves business processes	Low

Table 6-1: Summary of Findings and Themes

To provide support for the findings, claims are reasoned and their potential rival theories, if any, are considered and justified appropriately. From the discussion, important factors are identified and a conceptual framework is derived at the end of the chapter. The themes and factors are discussed in the following sections.

6.2 Important Factors Affecting RFID/SC Adoption

Finding 1: Compatibility, Readiness, and the Facilitating Condition are important factors in the evaluation of technology for adoption

Three factors have been found to have an effect on adoption in the case studies. They are Compatibility, Readiness, and the Facilitating Condition. In the group analysis, it was found that the suppliers and distributors were most likely to adopt RFID/SC whereas the retailers were not. The retailers in this case had lower perceptions of Compatibility, Readiness, and the Facilitating Condition than the suppliers and distributors. The contrast provides evidence that the three factors have some effects on the adoption of RFID/SC. In terms of Readiness and the Facilitating Condition, the suppliers believed that their environmental factors were favourable in facilitating the adoption of RFID/SC. They believed that their customers as well as the technology were ready. They also believed that support would be available to facilitate their adoption of RFID/SC if they needed it. The trialability of RFID and the availability of vendors to support the adoption were two highly contributing factors of a favourable adoption environment. These two aspects, trialability and availability, are categorised in the Facilitating Condition as the technological and environmental dimensions respectively, where the suppliers and distributors responded positively. Trialability allowed the suppliers and

distributors to try out RFID/SC in various forms that suited their business processes. As a result, they were able to determine specifically where RFID would be useful for them.

> *"We have done trials on [a variety of products]. We set up RFID portals and conducted tests on products and forklifts."*

The availability of RFID vendors to support their trials also provided a positive impression of the availability of support to facilitate RFID/SC implementation. In contrast, the retailers believed that their suppliers were not capable at that time and that RFID technology was not easily tested. In addition, they felt that there was neither expertise within their organisations nor qualified external vendors in New Zealand to support their RFID implementation.

Finding 2: The Facilitating Condition has some effects on Readiness

An in-depth interview with members of the case companies found that the Facilitating Condition is an important attribute in technology adoption. The initiation phase study found that most of the cases knew about RFID technology before they evaluated ways the technology could be useful to their businesses. In part of the evaluation, the ability to trial the technology and the availability of vendor support were important to the advancement of the initiation phase – that is, the decision to trial and subsequently to adopt or not to adopt the technology. When the cases formed a positive perception on the Facilitating Condition, they then had a positive perception on the Readiness.

> *"We had positive results of the trials. RFID is more compatible on drier product. We plan to have another trial in the next three months."*

Therefore, the case studies found that the Facilitating Condition has some influence on Readiness. Other supporting evidence from the case studies was the involvement of supply chain partners in RFID trials. Companies F and H were involved with their supply chain partners either directly or indirectly during their RFID trials. The ability to trial RFID with supply chain partners enabled the case companies to evaluate how ready their supply chain partners were for the technology.

> *"We found out after our trials and proposed to suppliers the type of standards to adopt, such as, active or passive tags."*

As a result of their trials, both Companies F and H claimed that their suppliers and customers on both ends of their supply chains were not ready for the technology. Both the companies indicated a higher intent of RFID future usage compared to the other supplier and distributor cases. These case companies had also indicated that their suppliers and customers were ready in the initial interview. These results support the finding that Readiness is positively related to the intention to adopt RFID/SC and that Readiness is impacted by the Facilitating Condition to a certain extent.

Finding 3: The Complexity of systems integration has some effects on Compatibility

When asked about the Compatibility of the RFID technology with their companies, the suppliers and distributors indicated that, in general, RFID was compatible. RFID allowed traceability of products along supply chains which had been a key attribute that the companies believed RFID technology could deliver. As a potential solution to supply chain visibility,

RFID was one of the few technologies that the companies were investigating. However, it is found that the Compatibility factor is relative to a company's existing infrastructure or machinery. For example, the manufacturers indicated that RFID was not compatible with their existing standards and systems. This could be due to the complexity of systems integration that the manufacturers foresaw if they implemented RFID.

> *"Technology [RFID] doesn't fit at the moment; cost is not an issue ... we buy raw material and build and install heavy machinery for our clients. [The manufacturing process is complex]."*

This was the case with Company C. A contrast to this is the example of the dairy cases. The dairy industry has been working on animal tracking using primarily manual or barcoding systems. The barcoding systems, which have similar characteristics, are more compatible with the RFID technology; therefore, it is not surprising that the dairy cases perceived highly on the Compatibility factor and the intention to adopt RFID/SC. Thus, Compatibility is positively related to the intention to adopt RFID/SC.

Finding 4: Compatibility and Relative Advantage are associated with one another

Further investigation revealed that Compatibility and Relative Advantage may be associated with one another. Using the above examples, the dairy cases both have higher perceptions of Compatibility and Relative Advantage, while the manufacturers' cases have lower perceptions in both. Due to the complexity of integrating RFID into their existing systems, the manufacturers perceived there was little benefit in adopting the technology. One of the manufacturers had adopted barcoding systems instead.

"No detailed study was carried out on RFID. There is no benefit for FMCG."

The distributors generally perceived the Compatibility and Relative Advantage factors positively. They perceived that RFID was compatible with their existing systems and processes while providing the benefits of product traceability and sharing of information.

"Having an end-to-end system gives information to our customers, who are on a separate system, for sharing [information]."

The survey found that the distributors believed that RFID speeds up order fulfilment and improves shipping accuracy. Thus, Compatibility and Relative Advantage are associated with one another in the context of RFID/SC adoption.

When considering a rival theory explanation (Yin, 2003), one could argue that a company could have a positive perception of the Relative Advantage of RFID as well as a lower perception of Compatibility. This could be true in the case of Company C, where the nature of their products did not suit the use of RFID for various economic reasons. Thus, RFID was perceived as incompatible with the company's existing values/beliefs. Barcoding systems were used instead by Company C. During their evaluation of RFID at the agenda setting stage, Company C had evaluated RFID based on the various operational issues they had, and had come to know about RFID when they were looking for solutions to their problems. Therefore, the evaluation would have been based on how well RFID could solve the problems and, thus, Relative Advantage over-ruled Compatibility in their case. This also applied to Company G where problems existed before RFID was presented as a potential solution.

However, most other cases reported that they knew about RFID first. In their agenda setting stage, the activities involved in information seeking about RFID were focused more on how compatible the RFID technology was with their existing systems and processes, rather than on the specific Relative Advantages of RFID/SC. This could be because they already knew of the benefits of RFID/SC and, thus, Compatibility took precedence over Relative Advantage.

> *"We are concerned with the systems integration."*

> *"We are trialling eight different models."*

Moore and Benbasat (1991) found in their study of individuals' adoption of personal work stations that their Compatibility and Relative Advantage constructs were in some way competing. They proposed more work was needed to explain the relationship between the two constructs. With the use of case studies that provided insight into causal processes (Yin, 2003), this research might have provided some clarity to Moore and Benbasat's (1991) call for an explanation. The evaluation of Compatibility and Relative Advantage using the TOE framework helped to explain the competing nature of the two factors. The perceived benefits of RFID/SC may have increased the interest but further investigation by organisations may find that the technology is not compatible with their existing systems or processes. This would lower the adoption intention. Thus, Compatibility and Relative Advantage are associated with one another. Perhaps the association is best explained by the MAF. Compatibility is described as the ability dimension, and Relative Advantage as the motivation dimension of the framework. Using the above example, the organisations may have the ability to adopt RFID/SC, but they may not be motivated due to the lack of benefits of using the technology in their processes.

In the case of the retailers, the Compatibility factor seemed to be inadequately assessed. While RFID was compatible with their existing systems and processes, the retailers perceived that RFID was less compatible with their suppliers and customers. It was found that the retailers were not actively involved in seeking information about RFID but, rather, had relied upon hearing or learning about RFID from peers and media sources. The results were mixed perceptions on RFID capabilities. Therefore, information about the technology influenced the perception of the Compatibility factor. Company K demonstrated this claim with their active involvement in RFID research, and they had related positively to the Compatibility factor. Compatibility could be further linked to how a company perceives the technology based on information from their sources; that is, the Subjective Norm of what others think about the company in terms of RFID usage.

Finding 5: The Subjective Norm has some effects on the level of engagement in information seeking about a technology

This research found some evidence that the Subjective Norm increased the information-seeking activities. For example, the case companies had participated in the survey (Soon & Gutierrez, 2008b) and later participated in the case study. This showed that, to a certain extent, they were involved in activities to seek more information about RFID. Four of the cases became members of the RFID Pathfinder Group formed by industry members in New Zealand to look at RFID development. This was particularly evident in the search for more information about the technical aspects of RFID, as the Group focused on business cases and technical standards. Cases that had high perceptions of the Subjective Norm also had high perceptions of Compatibility and Relative Advantage. This has been explained earlier in the

agenda-setting process – the companies were engaged in hearing and learning about RFID from peers, the media, and other channels. The level of engagement seems to be related to the companies' perceived Subjective Norm on what their supply chain partners think about their potential use of RFID/SC. For example, the retailers did not perceive that their supply chain partners thought they should use RFID so their level of engagement in RFID information-seeking was notably lower than the suppliers' and distributors'. This could lead to inadequate information when evaluating the Compatibility and Relative Advantage factors, which may explain the inconsistency found in the retailers' responses. Therefore, there is some support that the Subjective Norm influences the level of engagement in information-seeking which, in turn, affects the Compatibility and Relative Advantage factors. There is, however, no support that Subjective Norm has a direct influence on the intention to adopt RFID/SC. This will be explained in the next section.

Finding 6: Dependency on trading partners has some effects on technology adoption

Similar to the Subjective Norm, Pressure as a factor is found to be less important in the adoption of RFID/SC in this study. Instead, Dependency has been the key theme among the cases. Most cases were not susceptible to pressure to adopt RFID/SC. In the case of suppliers, although they claimed to be willing to adopt RFID when requested to by one of their key trading partners, they said they would not be under pressure to adopt the technology if they did not have a business case to do so.

"... it is about costs and benefits. There is no reason to push for the technology."

In the case of the distributors, they are more likely to adopt RFID/SC when asked due to their high dependency on their supply chain partners. Nevertheless, there were a few cases where Dependency was high but they claimed that they would not adopt under pressure.

> *"We rely on shippers for containers tagging … ultimately, needs are important but have to weigh with other technologies."*

These cases had done some form of trials on RFID and knew specifically where RFID would benefit their business. They would implement RFID in a more collaborative way rather than adopting for the sake of satisfying their trading partners. Thus, Pressure does not have much impact on the adoption of RFID/SC. It is the dependency on trading partners that has surfaced as an important factor and a common theme in the adoption of RFID/SC. Although the case companies could be under pressure from their trading partners to adopt RFID/SC, a commonality among them was that they would only adopt if there was a business case and the trading partners were important; not merely pressure from external parties. Hence, Dependency is a more appropriate explanation of RFID/SC adoption in this research than Pressure.

The impacts can be negative or positive depending upon the nature of the dependency on trading partners. The study showed that Dependency has indeed impeded the uptake of RFID. The suppliers in the case companies thought that they were ready and would adopt RFID when asked by their key supply chain partners. However, the distributors thought that the suppliers were not ready and, thus, were reluctant to push for adoption. On the downstream end of the supply chain, the retailers thought that their suppliers and customers were not ready. Although this may be a perceived Readiness issue, Dependency on trading partners

seems to have influenced the perception of facilitation that is required in technology adoption. The case of Company F, where their upstream supplier adopted RFID technology, supports this claim. With the upstream supplier adopting the technology, it facilitated the adoption of similar technology for Company F who would otherwise have looked at barcoding systems rather than RFID.

> *"One of our upstream partners is using RFID. We are exploring the possibility of utilising this."*

Dependency can also be looked at in terms of dependency on systems for business transactions. In the case of the manufacturers, they were highly dependent on their existing systems for their daily operations.

> *"Technology [RFID] doesn't fit at the moment; cost is not an issue ... we buy raw material and build and install heavy machinery for our clients. [The manufacturing process is complex]."*

Thus, they perceived the complexity of integrating RFID into the existing operations as a difficulty. As a result, the trial or adoption rate was lower for the manufacturers when compared to the dairy cases. Dependency, therefore, can be applied to the TOE framework for a more complete evaluation of technology adoption covering technological, organisational, and environmental aspects of technology adoption.

The following section discusses the less important factors found in the case studies.

6.3 Less Important Factors Affecting RFID/SC Adoption – Weak Support

Finding 7: The Subjective Norm may become an important factor in technology adoption when Dependency on trading partners is high

While the Subjective Norm increased information-seeking activities, there was no support to suggest that the Subjective Norm has a direct impact on RFID/SC adoption. It merely drove the search for more information in the case studies. For example, the retailers had high perceptions of the technological and organisational aspects of the Subjective Norm, but did not actively search for information. This could be due to their perceived Subjective Norm about their supply chain partners. The retailers perceived that their supply chain partners did not think that they should use RFID. However, they indicated a slight increase in usage of RFID over the ensuing three years, citing that their key trading partners might possibly adopt RFID.

> *"... a possible mandate from the Customs [government] or from big shippers or exporters ... it is not so much of a competitive advantage, but we like to do more for less and increase our services."*

Therefore, it can be argued that the Subjective Norm is important when there is a dependency on supply chain partners. If a company is dependent on its supply chain partners, the Subjective Norm of whether the company should adopt a technology or not becomes influential. This is similar to the individual adoption of technology, where several research

studies found the Subjective Norm is an important factor contributing to the intention to use IT (Brown, et al., 2002; Taylor & Todd, 1995).

Finding 8: Relative Advantage is less important than Compatibility but is a motivational factor that has some effects on the adoption of technology at the organisational level

In an earlier section, Relative Advantage is described as associated with Compatibility. Most of the cases' perceived Relative Advantage of RFID is based on their evaluations of its Compatibility. This could be a result of evaluating RFID as a priori knowledge of RFID before diagnosing the type of problems RFID could solve. Therefore, in the case of RFID adoption, where most of the cases knew of RFID technology before they looked at how it could solve their problems, Relative Advantage did not seem as important as Compatibility. This is demonstrated by the retailers, where they understood the advantages of RFID, but did not plan to adopt RFID. They depended more on the Readiness and Facilitating Condition factors. Thus, although Relative Advantage may create a favourable impression on the benefits of RFID/SC, it is not a strong indicator of adoption. Therefore, Relative Advantage is not an important factor in the adoption of RFID/SC. It is, however, described in this research as a motivation factor and is to a certain extent related to Compatibility.

The last factor that was discussed with the case companies was Privacy. It turned out to be an unimportant factor. It was unanimously agreed that Privacy is not a main concern in the adoption of RFID/SC. The case companies perceived there were proper policies in place to govern the use of information collected from RFID, such as in the case of credit card usage.

"Privacy would be an issue and not a concern at this stage. There are other priorities."

Their businesses were genuine and had every intention of maintaining respect for the privacy concerns of their customers and protecting their information. Since this is a part of their business processes and values, the case companies suggested that Privacy as a factor was not on the top of their concerns list. Thus, Privacy had a lesser impact on the adoption of RFID/SC.

6.4 Other Findings

Finding 9: Subjective Norm and Information Process are associated with one another

The case of Subjective Norms in technology adoption at the organisational level has not been well defined. Mathieson (1991) suggests that social norms will already have been considered in the evaluation of outcomes of technology acceptance. Its behaviour control aspect helps to highlight the circumstances surrounding technology adoption and, thus, is specific to its context (Ajzen, 1991). This research, with the help of the case studies, is able to draw insights into the role of the Subjective Norm in the adoption of technology within organisations. The findings of the retailers, which, without many information-seeking activities perceived that RFID/SC is a good technology, support Mathieson's (1991) suggestion. In its contextual role, the Subjective Norm may play a greater indicative role when an organisation is highly dependent on its trading partners. By chronologically evaluating the significance of the Subjective Norm in technology adoption, the impact of the quality of the information collected – driven by the social norms about the technology – on Compatibility, the Facilitating Condition, and Readiness, may actually change the perception of the Subjective

Norm. From that argument, there may be an existing informative link back to the Subjective Norm in the process of information-seeking and providing feedback. The feedback can be positive or negative depending on the nature of the information. As such, the Subjective Norm and Information Process are associated with one another in this study.

Other findings that emerged from the case studies relate to the role of the technology champions, the prioritisation of projects as strategy, and the "What comes first?" problem-technology chronology.

Finding 10: Organisations with a champion for IT adoption are more likely to adopt the technology than organisations without a champion for IT adoption

There are three distinct groups of champions found in the case studies. They are IT champions with an interest in RFID, champions who are Chief Financial Officers (CFO), and IT champions who are IT managers. The companies who had champions with an interest in RFID were more likely to conduct trials, although they might not be specifically on RFID. Only three out of nine cases with champions did not conduct any trials on RFID. Of the three cases, two of the champions were the company's CFO. It is found that, in New Zealand, it is common for the finance department to be in charge of IT projects as is the case for these two cases. There are also three cases in which the champions indicated a personal interest in RFID. All these three cases were involved in extensive trials, with two in the process of adopting the technology for their business. The other one had moved on to another company and the RFID project had since stopped progressing. Thus, in general, organisations with a champion for RFID are more likely to adopt the technology than organisations without a champion.

A rival explanation for Finding 10 is that organisations are likely to assign a champion to an IT project, hence, the high possibility of adoption cases where there is a champion. This is certainly a valid counter-proposition for the two CFO cases. However, investigating the chronological events, it was found that the three champions with an interest in RFID were more likely to actively search and push for adoption or trials. Their enthusiasm could have helped drive the adoption process.

> *"I have an interest in RFID. I have been following RFID closely in the past 18 months to research how RFID can be applied to [our business]."*

For the other cases where IT managers were the champions, it was primarily their job to look for potential solutions or emerging technologies for innovation.

> *"No detailed study was carried out on RFID. There is no benefit for FMCG."*

In the case of RFID, most IT managers had heard about RFID first. They subsequently participated in RFID meetings and were engaged in information-seeking. Therefore, the IT managers were in place before the RFID projects were commissioned for trials, and the IT champions were drivers to the adoption of RFID. From this point of view, there is support for Finding 10. Nevertheless, it is acknowledged that the technique used and the small sample size are limitations of this study to have a strong evidence for this finding.

Finding 11: IT projects are prioritised based on the budget allocated and their value to the organisation's strategy

In the two CFO cases, they were asked questions about RFID projects and their value to their companies. They were each tasked with the responsibility of driving their company's profitability with a certain allocated budget. One of the strategies for profitability is to use innovation. Thus, the CFOs claimed that they had a long list of IT projects waiting for implementation based on their organisations' strategies. RFID was just one of them.

> *"Cross-dock operation is now our main project. We are implementing barcode systems while being aware of RFID in our design consideration."*

Constrained by the annual budget and the need to perform in terms of finance and overall strategy, the CFO cases decided that RFID, although considered a key technology, was not on top of their to-do list.

> *"The costs of tags and infrastructure … they have to be value for money."*

> *"There is not much value as [the] barcode [system] is working. However, barcodes are not sufficient."*

The same applies to most of the IT managers who were the champions. They were either constrained by the budget allocated to them or they had too many waiting IT projects that were part of their long-term plans. Thus, another common theme of RFID/SC adoption is the organisation's strategy for technology adoption.

It should be noted that the prioritisation of projects requires further investigation which is beyond the scope of this research. The suggested research areas are how organisations allocate budgets to IT projects, what qualities of IS are measured when organisations prioritise IT projects, and how IT projects are incorporated into an organisation's strategy. This requires another set of research approaches and a separate framework. Nonetheless, to satisfy this research question, it is sufficient to highlight that organisations prioritise their projects according to their organisations' strategies.

Finding 12: Knowing the technology first results in a positive evaluation of the technology and how it improves business processes

It was found that most of the case companies knew about RFID before looking at how they could use RFID to improve their businesses. It is, therefore, the "how to improve their business", and not the "how to solve a problem" approach that most of the cases undertook. This is contrary to the cases where problems drove the need for RFID. In those cases, where problems came first, the search for RFID information was focused on how to fit RFID into their existing problems. This approach may make sense as organisations look for a solution to their problems. However, from the technology adoption point of view, the approach may be short-lived. The focus on an existing problem may cloud the true benefits of the technology in question. For example, Companies G and H, which thought that using RFID could ease their asset-tracking issue, did not do trials on the concept as they could not find a business case for their asset-tracking trials. They later found that by widening the implementation scope to other areas, they were able to justify the investment.

However, when the technology is evaluated from a technology point of view, the evaluator would adopt a systemic approach to how the technology can be implemented that would benefit their businesses. Thus, in studying the technology, the evaluator can determine what sort of problems the technology could potentially solve.

"RFID embedded in pallets can eliminate scanning error of barcode on pallets."

Therefore, instead of force-fitting the technology into their existing problems, organisations could better place the technology to improve their business. Similarly, as found in the case studies, understanding the technology first would most likely improve perceived Compatibility, which indirectly has some effects on Relative Advantage. In this case, Relative Advantage may be less important than Compatibility in the technology evaluation. Thus, understanding the technology first results in a positive evaluation of the technology and how it improves business processes.

6.5 Theoretical Framework of RFID/SC Technology Adoption

The findings discussed above are depicted in Figure 6-1. The figure shows the theoretical framework of the adoption of RFID/SC derived from the themes and findings uncovered from the case studies. The findings are numbered accordingly in the figure. The broken arrows indicate the weak supports found in the study that have some impacts on the factors pointed to. The solid-line arrows indicate an important influence on the intention to adopt RFID/SC.

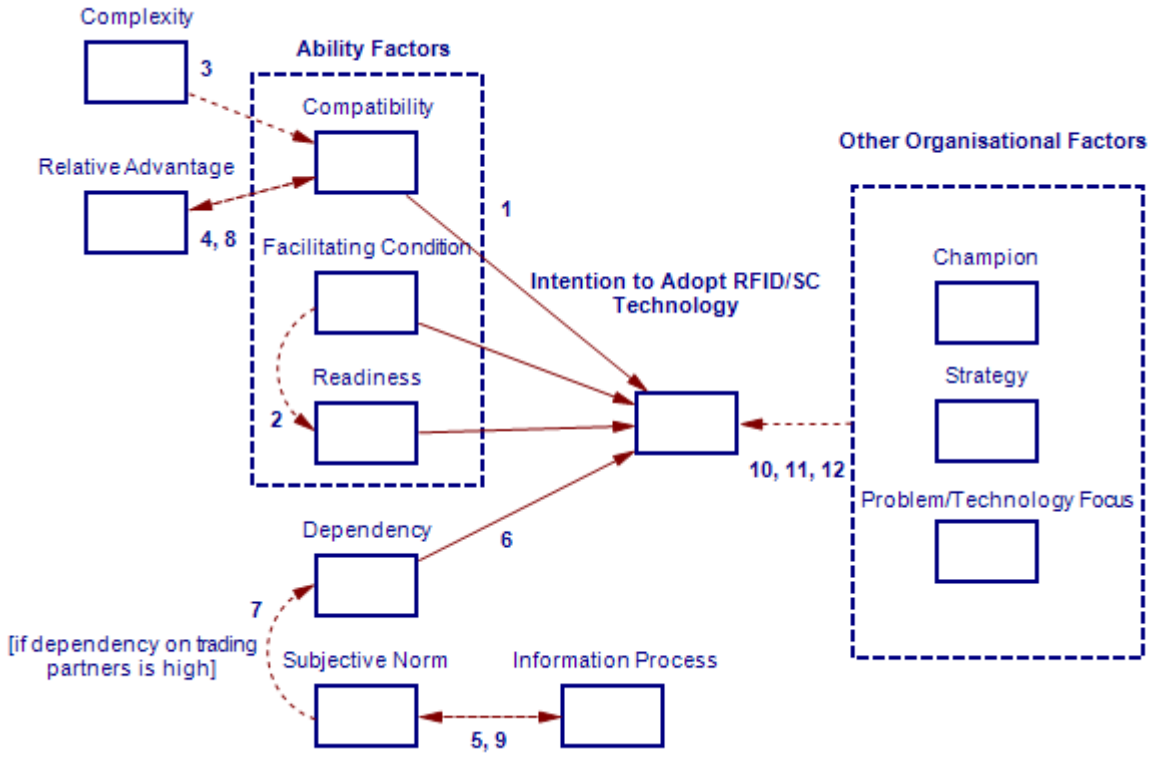


Figure 6-1: Proposed Theoretical Framework of RFID/SC Technology Adoption

It is worth highlighting that the three important factors – Compatibility, the Facilitating Condition, and Readiness – are classified as the Ability factors and the other less important factors are classified as the Motivation factors. There are two aspects in this assumption. First is the importance of the ability to innovate, as suggested in Christensen et al. (2004). Organisations require these Ability factors to facilitate the adoption of RFID/SC technology. This research shows that these are key factors for organisations when deciding on the adoption of RFID/SC which are clearly lacking in the New Zealand context in terms of achieving these factors. The good news, according to Christensen et al. (2004), is the government and other institutions can intervene to increase organisations' capabilities to innovate by creating technological or operational abilities. Operational abilities in this case include the facilitation of RFID implementation across supply chain partners.

Second, the fact that organisations are primarily concerned with the Ability factors means that they may already have their own Motivation to adopt RFID/SC. With Company C as an exception, most cases were able to find their own Motivation to innovate. Company C did not perceive the Relative Advantage of RFID due to the costs of implementation and, thus, was not motivated to explore the technology further. The company went for the cheaper barcode system. The other cases, like Companies G and H, were able to find their own Motivation by looking at a wider implementation scope that extended along their supply chains.

The further factors uncovered by the case studies are Complexity, Dependency, and other organisational factors such as the availability of a Champion, Strategy, and Problem/Technology Focus. It is found that the perceived complexity of systems integration had deterred the case companies from adopting the technology. This is especially obvious with the manufacturers as they are users of multiple systems and heavy machinery. The research found that perceived Complexity has an impact, indirectly through Compatibility, on the intention to adopt RFID/SC. In the evaluation of Compatibility of RFID technology with existing systems, Complexity seems to be a contributing factor to a lower intention to adopt RFID/SC. The more complex the perceived integration is, the lower the intention to adopt the technology. Complexity of systems integration is, therefore, included in the theoretical framework.

In the finding on Dependency, an interesting trend is discovered in the context of New Zealand supply chains. The suppliers and distributors were ready to adopt RFID/SC and were waiting for their supply chain partners to adopt. However, the retailers claimed that their suppliers and distributors were not ready and, thus, RFID was not a priority project. There is a

clear relationship of reliance among partners in supply chains that impedes the adoption of RFID/SC. Therefore, in the context of supply chain technologies, dependency on supply chain or trading partners is an important factor for adoption consideration. As such, Dependency is included in the theoretical framework.

The availability of a Champion, Strategy, and the Problem/Technology Focus are three other factors which surfaced as common feedback from the cases. They are all thought to influence the intention to adopt RFID/SC. These factors, as described in the preceding section, are primarily related to organisational behaviour. They are internal organisational factors. There is some evidence that the availability of an IT Champion drives the adoption process. The Champion is more focused on the technological aspects and is more likely to justify a business case with a proof of concept as a trial. However, when a technology is favoured, it would still have to be prioritised due to the limited resources and the organisation's strategy. Thus, the Strategy of an organisation is another factor that affects technology adoption. Many of the cases claimed that RFID was on their list of projects but just not on the priority list. They had other strategic projects planned for the near future. The third factor has been given a little more attention in the preceding section due to its impact on other factors such as Relative Advantage and Compatibility. The factor is the Problem/Technology Focus. The main point is how organisations approach the initiation stage of the adoption process. If the focus is on solving a problem, the matching of the technology and the problem will be limited only to the scope of the problem. However, if the focus is on technology, there is a higher chance of finding areas where the technology can be employed. In other words, it is the "finding a problem to fix" notion. There is nothing wrong with this notion especially from the perspective of continuous improvement. By understanding the technology, organisations will be able to evaluate how the technology can fit into their business processes and how it will

yield benefits. Therefore, it is assessed as having some impacts on the Relative Advantage and Compatibility factors.

6.6 Summary

A total of twelve findings are proposed in this chapter. The three factors classified as Ability factor and the Dependency factor are found to be important in the adoption of RFID/SC technology, while others are found to be less important with less impact. Together they are framed into a framework to provide as a guide to RFID/SC technology adoption.

While organisations have to find their own motivations to adopt RFID/SC, the government and other institutions can intervene to increase organisations' ability to innovate by creating technological or operational abilities or removing barriers.

The framework (Figure 6-1) is proposed to suit the evaluation of organisational technology adoption at the supply chain level. It provides important aspects of technology adoption that practitioners should be aware of when consulting or assessing a technology implementation. By considering the factors in the framework, it should provide managers with a useful guide in their quest to adopt a technology.

The next chapter provides more explanation of the framework and outlines the managerial implications.

CHAPTER 7 – CONCLUSIONS

7.1 Research Review

In the previous chapter, a theoretical framework of RFID/SC technology adoption was proposed. In this chapter, the research is concluded with revisiting the research objectives and questions. The chapter highlights what has been achieved and what has not been achieved. The proposed framework is then compared against other research studies and the importance of the findings is contrasted. Managerial implications, research limitations, and future research are highlighted as well.

Research Objective and Question

The objectives of this study are to find out the benefits and barriers of RFID technology, and to ascertain how organisations make the decision to adopt or not adopt RFID technology in supply chains. The three broad research questions proposed earlier in this research study were:

1. What specific benefits can be achieved in organisations by using RFID?
2. What are the barriers to realising these benefits?
3. How and why do organisations adopt or not adopt RFID in supply chains?

These questions are asked in a logical sequence that is aimed at uncovering the motivation to adopt or not to adopt RFID/SC. Therefore, the first aim was to understand RFID technology. A literature review on the development of RFID and its benefits was carried out to answer the first research question. The next logical question to ask was in relation to RFID adoption or usage. To find the answer to the second research question, an exploratory survey was

designed and conducted. The results of the survey were used to investigate the barriers further in order to identify the causes. This brought us to the third question on how and why organisations adopt or not adopt RFID/SC. A framework on factors affecting RFID/SC adoption is proposed as a result of the findings in the case studies. The rest of the section highlights the responses to the research questions.

Research Question 1 – What specific benefits can be achieved in organisations by using RFID?

As part of answering Research Question 1, an extensive literature review on RFID was conducted. The literature review started by investigating the development of RFID in various industries. It covered the birth of RFID and the EPC at a MIT laboratory. The various classes and frequency ranges used in RFID were also discussed as they are crucial to the adoption of RFID and the inter-operability of RFID applications worldwide. The lack of agreement on an RFID standard around the use of frequency was found to be a barrier to the adoption of RFID. Other barriers found were costs, reliability and privacy concerns.

An important overview of this research question was undertaken in the literature review found in Chapter 2. The chapter reviewed the important aspects of RFID and supply chain management. The review shows some of the benefits of RFID/SC. The increased visibility of supply chain activities, improved delivery efficiency, shipping accuracy, and reduced inventory and labour costs are the main benefits of RFID/SC. A further look at the benefits among the supply chain members provided a clearer picture of the effects of RFID adoption in supply chains. The potential benefits of RFID might change the way supply chains operate and could shift the control of the supply chain to the retailers. The literature review shows that large retailers such as Wal-Mart and Tesco were issuing mandates to their suppliers to use

RFID. It seemed that the retailers had more to gain with the technology. A traditional supply chain works as the manufacturers push the supplies and the retailers struggle to manage their demands. A few innovations or concepts were adopted to smooth the traditional supply chain operations. For example, ERP and EDI are the traditional technologies adopted to manage information between trading partners in supply chains. Just-in-time and other productivity concepts are deployed to reduce costs associated with supply chain inefficiencies. On the demand side, QR, CPFR, and ECR are some of the techniques used to manage demands and replenishment. More importantly, they are used to manage product category sales forecasts which are an important retailing concept. RFID is seen as a technology to accelerate the adoption of the above techniques and concepts by providing the capability of real-time product information along supply chains.

The literature review also highlights concerns regarding RFID/SC. The issues are the standards, reliability, costs, and privacy concerns of using RFID in supply chains. Besides these specific issues, there are also impacts on businesses. One of the impacts is the effect of mandates on supply chain management. This impact triggers the need to look at how disruptive technology behaves and how to mitigate the impact. Three tiers of effects, each a cause of the latter, are described and highlighted in the literature review.

An important outcome of the literature review is the identification of enablers of RFID/SC adoption from the literature. The enablers are factors that are prerequisites of RFID/SC adoption and, thus, form the scope for this research.

Research Question 2 – What are the barriers to realising these benefits?

Research Question 1 provides an overview of the benefits that RFID brings to businesses. The benefits are different for each supply chain member. The retailers appear to have an obvious beneficial gain in procurement power with use of the technology. Nevertheless, there is certainly a lot of potential for the suppliers and distributors to benefit as well; possibly even a chance to dominate their supply chains with RFID. While organisations around the world were having a serious look at RFID/SC, New Zealand organisations seemed to be lagging behind in the usage of the technology. Thus, Research Question 2 seeks to define the barriers to the adoption of RFID/SC and to realising the benefits.

To answer this research question, an exploratory survey was conducted. The results of the survey show that the goals and objectives of RFID/SC for businesses are somewhat similar to those found in the literature review. They are to improve inventory visibility, achieve labour efficiency and product traceability, and speed up order fulfilment as the most commonly-picked answers on the benefits of RFID/SC. The barriers, to answer this research question, are the lack of agreed-upon standards, integration, and expertise or knowledge to deploy the technology. The survey also sheds some light on the differences between the adopters and non-adopters, and the experiences faced by the adopters. It highlights the gaps between the adopters and the non-adopters in terms of the concerns around the compatibility of the RFID standards, data security, scanning accuracy, and the usefulness of the data collected by RFID applications. It also draws attention to the overall difficulty of systems integration and standards compatibility experienced by the adopters. This clearly points the research in the direction of compatibility issues and other classic technology adoption experiences like support, ability and facilitation as the enablers. Another potential barrier to the adoption is the cost of implementation. For an on-going business, the main drivers to adoption of any

technology are the costs and benefits of doing so. Budgets, funds, and other factors that affect the businesses' bottom-line are key concerns for business owners. Further questions were derived from the survey.

1. Are the lack of agreement on standards, integration, and expertise the true technology barriers to RFID adoption?
2. How important is investment cost to an organisation when evaluating RFID in supply chains?
3. What are the motivational and ability factors that drive RFID in supply chains adoption?
4. How does an organisation proceed with the assessment of RFID in supply chains that leads to the decision to adopt or not to adopt RFID?

These questions were used as an inquiry in Research Question 3 to explore the behaviours of organisations when evaluating RFID for possible adoption in their supply chains.

Research Question 3 – How and why do organisations adopt or not adopt RFID in supply chains?

The aim of Research Question 3 is to help businesses know their capability and the barriers of RFID adoption when they decide to adopt or not adopt RFID/SC. The above four questions form the underlying guideline to the design of the case study approach for answering Research Question 3.

Various technology adoption theories and frameworks were used in this part of the research. Organisational and individual technology adoption theories were reviewed and relevant

adoption factors were studied for the case study. In agreement with the exploratory survey, the case studies provided evidence that Compatibility, the Facilitating Condition, Readiness and other factors are important in the adoption of technology. Therefore, the question on the lack of agreement on standards, integration, and expertise as barriers to RFID adoption is valid.

The question on the importance of investment cost was initially perceived as a potential barrier. Return on investment is a key financial indicator used by businesses to assess the risks and benefits of their investments. However, the case studies find that the cost of implementation is not a key factor organisations would consider when evaluating the adoption of RFID. It is perceived that benefits surpass costs in IS adoption. It was found that the case companies have a formal process for prioritising their investment projects based on their organisation's strategy, enabling proper funding or allocation of budget to be planned for the priority projects. Thus, investment cost is not a deciding factor in the evaluation of RFID technology.

Christensen et al.'s (2004) framework on Motivation and Ability provides a good guide to the removal of barriers to RFID adoption. The case study findings indicate that Ability factors are among the key barriers to the intention to adopt RFID/SC. There is some evidence that New Zealand businesses have their specific motivations for RFID adoption. However, they are lacking in their ability to execute the adoption in terms of systems integration and technical issues. The MAF explains that governments or commercial/industrial institutions can help facilitate the adoption by providing the ability to do so, such as, expertise. Therefore, using the MAF and the theoretical framework of RFID/SC technology adoption proposed in this

research, organisations can evaluate their own Ability factors in their planning for an RFID-enabled supply chain technology adoption.

This brings the study to the last question about how organisations behave when they assess a technology for adoption. The case studies reveal several factors that may influence the decision to adopt or not to adopt a technology. This is discussed in the two stages of the initiation phase of the innovation process. In the agenda-setting stage, organisations are involved in information-seeking about the technology. Factors such as the Subjective Norm and Relative Advantage have some impacts on the evaluation of the technology as perceived by the organisations involved. Also, to a certain extent, perceived Complexity is an important factor. It has some impacts on the Compatibility of the technology which, in turn, has an influence on adoption decision-making. In the matching stage, Ability, Dependency, and other organisation factors are a key to the evaluation of technology. At this stage, organisations are assessing how well the technology fits their businesses. This includes their capability, as well as that of their trading partners, to implement the technology. Within each organisation, there are several considerations such as the significance of the project, the focus of the organisation, and their interest in the technology. These considerations may influence how the organisations approach technology adoption.

7.2 Research Contribution

The framework proposed in this research helps to bring out the important factors in the adoption of RFID/SC. While most IS research is focused on individual technology adoption or on intra-organisational technology adoption, this research is focused on technology adoption that involves or has impacts on trading partners, that is, at supply chain level. It

provides a three-dimensional evaluation framework which includes technological, organisational, and environmental aspects of inter-organisational technology adoption.

The contribution of this research to the field of operations management and supply chains is the introduction of well-known IS theoretical frameworks. The use of these theories to evaluate supply chain technology adoption not only introduces a new theoretical framework (Figure 6-1), but adds to the knowledge of the supply chain and operations management discipline which was lacking on IS perspectives.

7.2.1 Contribution When Compared with Other Research

The proposed theoretical framework of RFID/SC technology adoption (Figure 6-1) is discussed in four parts. Part A discusses the three Ability factors in organisational technology adoption. Part B highlights the findings of this study that show insights into how organisations evaluate the Compatibility factor of the technology concerned via the Complexity and Relative Advantage factors. Part C highlights another finding that concerns the frequently studied Subjective Norm and its role in information-seeking. Lastly, Part D highlights the other three findings that make up the organisational factors: Champion, Strategy, and Problem/Technology Focus. Figure 7-1 highlights the four parts using the proposed framework.

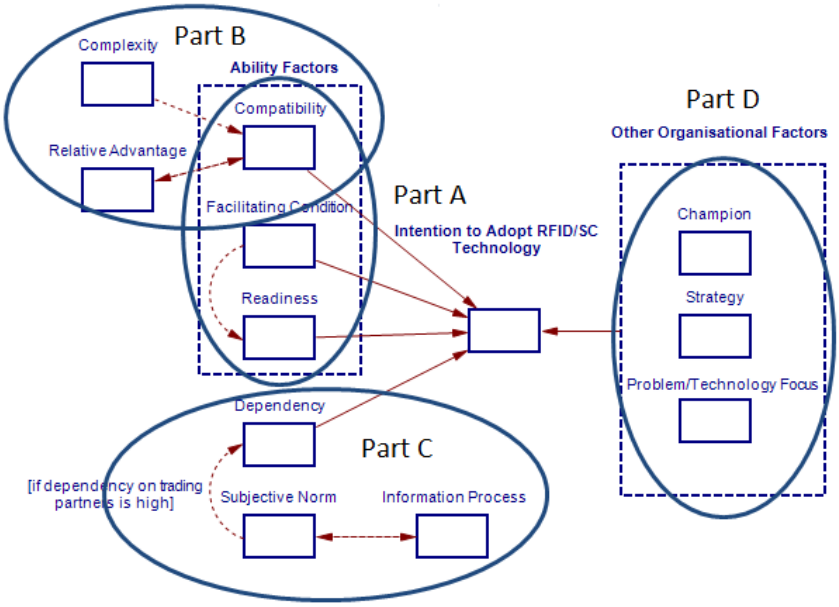


Figure 7-1: The Four Parts of the Research Contribution

Part A

Finding 1: Compatibility, Readiness, and the Facilitating Condition are important factors in the evaluation of technology for adoption

Finding 2: The Facilitating Condition has some effects on Readiness

Part A shows three factors from the case studies that are found to be influential in the intention to adopt or use RFID. Compatibility is by far the most commonly found factor in the organisational technology adoption literature. This means that organisations evaluate whether the technology is compatible with their existing values, past experiences and needs (Rogers, 1995). In this research, the Compatibility factor includes consistency with existing technological standards and those of other trading partners in supply chains. Similarly, Premkumar, Ramamurthy and Nilakanta (1994) in their study of EDI find that technology standards are important to EDI adoption. They link Compatibility to the adaptation of data formats and hardware/software standards. They found that it was most obvious in the linking

of multiple suppliers with multiple customers. This is also the case in RFID/SC. Distributors were faced with the dilemma of what standards to adopt while having to serve multiple customers. As a consequence, the distributors were not willing to take the lead with the technology but rather they preferred to wait. Singh, Lai and Cheng (2007) found that supply chain technology has to be aligned with organisational practices and policies and, indeed, it has to be compatible with organisational values. In most instances, the case companies evaluated RFID based on their requirements and needs. For example, the distributors were concerned with the efficiency and accuracy of inventory and order fulfilment and so believed RFID performance in those areas was important to them.

Readiness is also found to be consistent with results in prior studies. IT knowledge and the adequacy of technology resources are two of the aspects of Readiness being evaluated when adopting a technology (Kuan & Chau, 2001; Mehrtens, et al., 2001). Not included in the measurement of Readiness in this research study are the financial resources. This is related to investment cost. It was explained earlier that investment cost, although important, is not a concern to the case companies in the evaluation of technologies. Iacovou et al. (1995) find that financial capability has no significant impact on the adoption of IS, and that finding is supported by this study.

The Facilitating Condition is another commonly-cited factor in IS adoption. The use of the Facilitating Condition in this research study is similar to other individual factors used by other IS research studies. For example, trialability is used in Jimenez-Martinez and Polo-Redondo (2004), and vendor support is used in Al-Qirim (2005) and Chau and Hui (2001) as a separate factor in their study of IS adoption. As with these studies, the Facilitating Condition measured in the TOE dimensions is found to be important in technology adoption. Trialability is

evaluated as important to pre-adoption assessment of the technology. Being able to try out RFID helps organisations to evaluate the Compatibility of technologies. This research finds that, in most cases, companies decided not to adopt RFID after some trials. There are also many instances of suggestions that there was a perceived lack of external expertise or knowledge to assist organisations in their implementation. Overall, organisations evaluate the technology based on whether the technology can be tested and whether there is sufficient expertise or knowledge internally and externally to assist in the implementation.

Trialability factor as a determinant of whether there are resources available to facilitate the implementation of the technology could be the link between Facilitating Condition and Readiness. It was argued that it might happen during trials where an organisation came to realise that a trading partner was not ready for adoption. For this reason, there is a possible influence of the Facilitating Condition on the Readiness of an organisation since trialability is a facilitating condition. Matta (2008) in his PhD research finds that top management is "critical in providing adequate resources and developing a supportive climate for adoption of new technologies" (p. 71). By providing adequate resources and a supportive environment, an organisation will be well-positioned in terms of the Readiness factor for technology adoption.

Part B

Finding 3: The Complexity of systems integration has some effects on Compatibility

Finding 4: Compatibility and Relative Advantage are associated with one another

Finding 8: Relative Advantage is less important than Compatibility but is a motivational factor that has some effects on the adoption of technology at the organisational level

Part B explains the relationships uncovered between Complexity, Relative Advantage and Compatibility. While Compatibility is defined as an important factor in the adoption of RFID/SC, its assessment is somewhat influenced by the perceived Complexity of systems integration. Rogers (1995) defined complexity as the degree of perceived difficulty to understand and use. Complexity is also used as a separate variable in the evaluation of innovation diffusion by Premkumar et al. (1994) in their EDI adoption study. Complexity was hypothesised as having a negative impact on EDI adoption. Premkumar et al. (1994) state that although a technology may be useful, there may not be expertise within an organisation to implement or use it. The technology may be perceived as complex and difficult to understand and use. Nonetheless, complexity was not found to be a significant factor by Premkumar et al. (1994). This could be explained by the technical compatibility which was found as a key predictor of EDI adoption and internal diffusion in their study. Technical compatibility was defined by Premkumar et al. (1994) as the perceived consistency with present systems such as data formats, hardware/software, network protocols, and electronic interaction with trading partners. Subsequent diffusion becomes more complex and problematic as the technology is introduced to other departments. It would require more commitment and major changes to processes or work practices and was, thus, perceived as incompatible. It is noted that in their explanation, Premkumar et al. (1994) suggest that an inherent feeling may exist that the innovation is faulty and, as a result, problems with existing hardware/software and standards

may deter diffusion. From the results, it seems that Complexity is embedded in the technical aspect of the Compatibility factor. Similar to this research finding, Premkumar et al. (1994) suggest that technical compatibility as a result of complexity has, to a certain extent, an impact on adoption and internal diffusion, defined as the initiation phase in this study. Thus, there is support for the finding that perceived Complexity of systems integration has some effects on Compatibility.

Relative Advantage is found to be less influential in this research study. However, it has been found to be important to IS adoption in other research (Iacovou, et al., 1995; Plouffe, Hulland, & Vandenbosch, 2001; Premkumar, et al., 1994). In this research study, it is found that because the evaluation of RFID/SC adoption included the technological aspects, Compatibility becomes a more important factor in the intention to adopt RFID/SC. This is supported by the finding of a case where the approach to the evaluation of RFID/SC is from the point of view of existing problems that require solutions (it is acknowledged that this is limited to only one case). The perceived benefits of RFID were found to be important to them as the organisation searched for a better idea to supersede their existing innovation. Plouffe et al. (2001), although finding that Relative Advantage is a influential factor, caution that it is a collection of other factors that is equally, if not more, important than Relative Advantage. They argue that other innovation characteristics have a direct impact on intentions without the effects of usefulness or Relative Advantage. Their argument is supported by other studies such as Agarwal and Prasad (1997), and Chin and Gopal (1995). Both studies found that Compatibility was more important than usefulness as a predictor of intentions. It is, thus, consistent with the finding of this research study that Relative Advantage is less important than Compatibility. What was not explained in the prior studies was the possible association of Relative Advantage and Compatibility with one another. The case studies in this research

show that the perceived benefits of RFID/SC are aligned with the Compatibility concerns. That is, RFID application is perceived as a fit with the organisation's existing systems and processes in areas that have the highest perceived benefits. Thus, organisations evaluate the technology against their core competency in terms of Compatibility and Relative Advantage. It is also found in this research study that Relative Advantage may be the first consideration in the early stage of the evaluation of a technology. When it comes to the intention to adopt the technology, however, Compatibility seemed to play a larger role as a potential barrier to adoption. In agreement with prior studies, Relative Advantage is secondary to Compatibility as a predictor of intentions.

Part C

Finding 5: The Subjective Norm has some effects on the level of engagement in information seeking about a technology

Finding 6: Dependency on trading partners has some effects on technology adoption

Finding 7: The Subjective Norm may become an important factor in technology adoption when Dependency on trading partners is high

Finding 9: Subjective Norm and Information Process are associated with one another

In this Part C discussion, the Subjective Norm and Dependency are two factors of concern. The Subjective Norm has been widely studied in the IS field. Most of the studies have found the Subjective Norm to be an important factor of intention behaviour (Brown, et al., 2002), particularly in organisational settings (Taylor & Todd, 1995). There are some cases where the Subjective Norm is found not to be important to the adoption decision. For example, Davis et al. (1989) found that the Subjective Norm is not a significant predictor of intentions in personal and individual application adoption.

In this research study, there are three findings about the Subjective Norm. First, the Subjective Norm is less influential compared to Compatibility, Readiness, and the Facilitating Condition. It is only influential when Dependency on trading partners is high. Second, the Subjective Norm has some effect on information seeking activities and, third, the Subjective Norm is associated to the Information Process. In contrast to prior studies where the Subjective Norm is found to be a factor in organisational settings, it was found in this study that it was not an influential factor in the intention to use RFID/SC. This could be due to the small sample size of this case study. Davis et al.'s (1989) explanation of the system application as personal and individual does not apply in this case: RFID/SC is a multi-organisation application. Instead, it is found that the Subjective Norm increased the search for information about RFID/SC. Most cases heard about RFID/SC and started enquiring about the technology. In their later stages of information processing, the cases may have shifted their evaluation from social influence to a more realistic organisational setting that involves internal organisation members. The internal members would base their evaluation on what is best for their organisation. In this case, Compatibility, Readiness, and the Facilitating Condition stand out as key factors. The Subjective Norm may trigger the information-seeking process and it may become less important when organisations formally start to consider the adoption decision. As the organisations form an understanding of the technology through rounds of information processing, their Subjective Norm may again shift as a consequence. One of the cases in this research study claimed that they might change their adoption status if they see real benefits when their trading partners start to yield a return on investments with RFID.

This brings the discussion to the finding of Dependency as a factor. In prior studies, Dependency has been studied in the adoption of EDI. It is often studied as an external

pressure or coercive pressure (Iacovou, et al., 1995; Teo, et al., 2003). Dependency on trading partners or government has been found to be important in the adoption of organisational applications. Organisations that are highly dependent on their trading partners or government are willing to adopt technology when requested. The fact that some case companies in this research study are willing to adopt RFID/SC when requested by their trading partners suggests that the Subjective Norm becomes important when the case companies are highly dependent on their trading partners.

Pressure in this study is found not important as most cases claimed that although they were willing to adopt when asked, the adoption is subject to feasibility of the implementation. This is in contrast to Matta's (2008) finding that external pressure is important in his study of RFID adoption in the US. This can be explained by the mandate to adopt RFID and the penalties imposed by retailers on deliveries that are not tagged with RFID (Matta, 2008). It is acknowledged that the assumption for Pressure is not supported based on the responses from the case companies. There appears to be some competition between the Dependency and Pressure factors. While Dependency surfaces from the cases as an important consideration in their decisions, Pressure to adopt technology has been put off by the cases. Based on the fact that prior studies have found Pressure to be influential in the intention to adopt inter-organisational technology, this research refrains from concluding that Pressure is not an important factor in RFID/SC. Instead, it urges interested researchers to investigate the equivocality of Pressure and Dependency as found in this research study. It is believed that Pressure may be important at a different stage in the technology life-cycle or among the roles of the supply chain members. Nevertheless, based on the textual analysis of the case study, Pressure is not an influential factor in this research.

Part D

Finding 10: Organisations with a champion for IT adoption are more likely to adopt the technology than organisations without a champion for IT adoption

Finding 11: IT projects are prioritised based on the budget allocated and their value to the organisation's strategy

Finding 12: Knowing the technology first results in a positive evaluation of the technology and how it improves the business process

Part D presents research findings that are related to an organisation's internal factors. The first finding is the role of a champion in driving technology adoption. Recent studies on champions use a charismatic leadership theory to measure the level of influence of championship in technology adoption (Neufeld, Dong, & Higgins, 2007; Wixom & Watson, 2001). The studies look at the leadership charisma in managing IS adoption. In their study on EDI implementation, Premkumar et al. (1994) find that a champion in an organisation is typically the one who initiated the IS implementation and, thus, is motivated to ensure its success. There are two cases in this research study where the IS projects are initiated by a champion in the organisation. In this research study, it is identified that the role of the IS champion affects the adoption. For example, if the champion is the CFO of an organisation, his or her interest will be to make sure that the organisation's finance sheet is balanced; the importance of an IS project may not be as important in the CFO's interest.

This brings the study to the second finding, Strategy. Prioritisation of projects aligned with an organisation's strategy has been a common budget management approach to ensure that funds are available for important or critical projects. There is not much literature specifically on the impact of prioritisation projects on technology adoption. The closest to prioritisation is the

study of top management support in technology adoption (Daugherty, et al., 1995; Kieckhaefer & Inderrieden, 1987; Matta, 2008; Walton, 1996). Projects that get top management support are likely to be on the priority list and, thus, are more likely to be implemented. However, this research study suggests investigating how the top management evaluate and prioritise IS projects based on their organisation's strategy.

The third finding is the notion of what comes first, the problem or the technology. It had not been well studied in the IS field when this research started. The question on what comes first is adopted from Rogers (1995). He suggests the difference between "problem first" and "knowing the technology first" is the main activity involved in information seeking. If an individual came to know about an innovation by chance, the individual might not actively seek information about the innovation (Rogers, 1995). The finding of this research is not on the level of information search but rather on the attitudes toward finding the right information. Thus, if an organisation approaches the information-seeking activity with a problem, the information that they are exposed to would be specific to the problem. This increases the risk of errors and bias on the evaluation of the IS. Thus, the process of selective perception (Rogers, 1995), referred to as the problem/technology focus in this study, may have, to a certain extent, an effect on technology adoption decisions.

Due to the fact that these three findings are new to this research area, more investigations are warranted to validate the effects they have on technology adoption.

There are many contributions by the research as discussed above. Most of these contributions have managerial implications that are discussed next.

7.2.2 Managerial Implications

There are four key managerial implications worth pointing out. First, organisations need to possess the Ability variables to be in a position to start the RFID adoption process. The technology needs to be compatible with the organisation's systems as well as with its trading partners' systems. The organisation's and its trading partners' infrastructure need to be ready for such a supply chain technology. Facilitating trials with trading partners helps to highlight the readiness of their supply chain as well as possible teething issues with compatibility.

Second, organisations need to gather not only adequate but relevant information about RFID so that appropriate levels of evaluation can be conducted. The Subjective Norm of the cases informs the study that inadequacy of relevant information led the retailers to different assumptions. Organisations can get the latest information about a technology by attending industry and academic forums and, in particular for RFID standards, the local government privacy and radio wave commissions are highly recommended sources of information.

Third, in the case where the Dependency on trading partners is high, information about the organisation's trading partners is even more important. The mixed perceptions of their suppliers' and customers' readiness have misinformed the cases that their supply chains were not ready for RFID. Thus, collaboration is crucial at the supply chain level. Organisations need to collaborate and work with actual information.

Fourth, there are other internal considerations for organisations. Organisations may need a project champion with the leadership to drive an important technology adoption project. While projects are prioritised according to the organisation's strategy and financial position, getting support from the management can be critical to the success of the project

implementation. In order to get the relevant support from the management, managers have to understand a technology well to be able to form an appropriate business case for the adoption of the technology.

This RFID/SC adoption framework hopes to inform practitioners with useful guidelines in their quest to adopt RFID/SC.

7.3 Research Limitations and Future Research

In this study, as with all research, there are limitations. While this research demonstrates strong validity in terms of the knowledge of the subject and the literature review, the reliability of the research is somewhat difficult to measure. RFID/SC as a topic in the IS and operations management field is fairly new. As such, there are only a handful of research studies on the topic specifically in the supply chain context. In order that the research can be replicated by another researcher, the theories used were carefully selected and crafted to suit the context and to avoid errors or biases in the study (Yin, 2003). To prove that the theory proposed by this research is valid, other researchers are asked to use a similar approach to other contexts such as in the mobile or electronic commerce literature.

Another limitation follows on from the above limitation. This research is a cross-sectional empirical study. Data collected are thus a “snap-shot” of the perceived evaluation by the cases studied. As part of the research is to determine how organisations can overcome the barriers identified, a longitudinal approach may well fit this intention. Unfortunately, due to the short timeframe available for this research and the fast changing pace of organisations, the research design is limited to a self-reported snap-shot of the case companies’ intentions to use or adopt

RFID. With careful interpretation of the data, the research is capable of achieving the desired research quality and has achieved the objectives of the thesis.

Last but not least, another limitation of this research lies with the selected organisations for the case studies. Although the selection of cases has gone through a rigorous process, it is acknowledged that the available cases are only a fraction of organisations in New Zealand that were involved in RFID in some way. Again, as with the second limitation, the research is constrained by the available time. Therefore, a "best effort" approach is adopted to select the cases that are representative of RFID adoption in New Zealand.

With the limitations acknowledged, the research presents opportunities for further research within those limitations and the others discussed earlier. The research should be replicated in other cross-organisation technology adoption such as the EDI. This approach will validate the proposed framework making it a more adaptable framework. Another approach to validate the proposed framework is to conduct a longitudinal study to affirm the findings found by this research. The focus could be on specific supply chain members such as in the transport industry, courier services, and primary produce sectors. Finally, this research proposes to investigate the effects of champions, project priority, and problem/technology focus (selective perception) on technology adoption.

7.4 Publications from this Thesis

Soon, C. B., & Gutierrez, J. (2010). RFID Technology Adoption in New Zealand Supply Chains: A Case Study Approach. *Pacific Asia Journal of the Association for Information Systems, 2*(3).

Soon, C. B., & Gutierrez, J. (2010). *Prediction of RFID Performance in Supply Chains*. Paper accepted for the Proceedings of the 16th Americas Conference on Information Systems, Lima, Peru. Manuscript ID: AMCIS-0214-2010.R1.

Soon, C. B. (2009). Chapter 1: Radio Frequency Identification History and Development. *Auto-Identification and Ubiquitous Computing Applications: RFID and Smart Technologies for Information Convergence.* Symonds, J., et al. (Eds). NY, Information Science Reference.

Soon, C. B., & Gutierrez, J. (2009). Recognizing RFID as a Disruptive Technology. *International Journal of Information Systems and Supply Chain Management, 2*(1), 55-68.

Soon, C. B., & Gutierrez, J. A. (2008a). Effects of the RFID Mandate on Supply Chain Management. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 81-91.

Soon, C. B., & Gutierrez, J. A. (2008b). *Where is New Zealand at with Radio Frequency Identification in the Supply Chain? - A Survey Result.* Paper presented at the Proceedings of 2008 International Conference on Information Resources Management, Niagara Falls, Canada.

APPENDIX A

This table shows the literature in RFID in Supply Chain published between 2007 and 2009 from the ABI/INFORM global database. The articles are arranged in order of the publication year and month as arranged by the search engine. The nature of the study and research methods are checked for each article. The search criteria are: RFID and "Supply Chain" as the key words, specific date ranges and only scholarly journals including peer reviewed.

Research	Year	Benefits / Issues	Implementation	Adoption	Review / Classification	Survey	Case study	Technical*
Lee & Özer, 2007	2007	x			x			
Gaukler, Seifert, & Hausman, 2007	2007		x				x	
Srivastava, 2007	2007		x				x	
Sellitto, Burgess, & Hawking, 2007	2007	x			x			
Li & Chandra, 2007	2007	x					x	
Kumar, 2007	2007							x
Miller, 2007	2007							x
Erickson & Kelly, 2007	2007	x			x			
Loebbecke, 2007	2007		x				x	
Kelepouris, Pramatari, & Doukidis, 2007	2007							x
Connolly, 2007	2007	x			x			
Chow, Choy, Lee, & Chan, 2007	2007							x
Koo, et al., 2007	2007			x		x		
Chao, Yang, & Jen, 2007	2007	x			x			
Pramatari, 2007	2007		x				x	
Attaran, 2007	2007	x			x			
Gessner, Volonino, & Fish, 2007	2007							x
Swartz, 2007	2007	x			x			
Bendoly, et al., 2007	2007			x		x		
Amini, Otondo, Janz, & Pitts, 2007	2007							x
Delen, Hardgrave, & Sharda, 2007	2007	x					x	x
Heese, 2007	2007	x						x
Whitaker, et al., 2007	2007			x		x		
Fink, Gillett, & Grzeskiewicz, 2007	2007	x			x			

Research	Year	Benefits / Issues	Implementation	Adoption	Review / Classification	Survey	Case study	Technical*
Rekik, Jemai, Sahin, & Dallery, 2007	2007	x					x	
Visich, Li, & Khumawala, 2007	2007							x
Hingley, Taylor, & Ellis, 2007	2007		x				x	
Datta, Granger, Barari, & Gibbs, 2007	2007							x
Langer, Forman, Kekre, & Scheller-Wolf, 2007	2007		x				x	
Rundh, 2008	2008	x						x
Liu, Tang, & Huang, 2008	2008							x
Loebbecke & Huyskens, 2008a	2008	x					x	
Ramudhin, et al., 2008	2008							x
Zhang, Ouyang, & He, 2008	2008				x			x
D'Mello, Mathews, McCauley, & Markham, 2008	2008							x
Wamba & Boeck, 2008	2008							x
Soon & Gutierrez, 2008a	2008	x			x			
Veeramani, Tang, & Gutierrez, 2008	2008		x				x	
Shih, et al., 2008	2008	x		x		x		
Wang, Liu, & Wang, 2008	2008							x
Lee, Fiedler, & Smith, 2008	2008		x				x	
Wamba, Lefebvre, & Bendavid, 2008	2008	x						x
Bottani & Rizzi, 2008	2008	x				x		
Cannon, et al., 2008	2008	x		x	x			
Luo, et al., 2008	2008	x						x
Crazier, Jensen, & Dave, 2008	2008	x						x
Chang, et al., 2008	2008			x		x		
Uhrich, Sandner, Resatsch, Leimeister, & Krcmar, 2008	2008							x
Loebbecke & Huyskens, 2008b	2008		x				x	
Boeck & Wamba, 2008	2008						x	x
Uçkun, Karaesmen, & Sava, 2008	2008							x
O'Leary, 2008	2008							x
Moon & Ngai, 2008	2008	x					x	
Powanga & Powanga, 2008	2008	x			x			
Enyinda & Szmerekovsky, 2008	2008	x			x			
Szmerekovsky & Zhang, 2008	2008		x				x	x

Research	Year	Benefits / Issues	Implementation	Adoption	Review / Classification	Survey	Case study	Technical*
Mehrjerdi, 2008	2008				x			x
Lee & Park, 2008	2008		x					x
Krotov & Junglas, 2008	2008	x			x			
Tu & Piramuthu, 2008	2008							x
Sabbaghi & Vaidyanathan, 2008	2008	x			x			
Chuang & Shaw, 2008	2008		x			x		x
Ju, Ju, & Sun, 2008	2008	x			x			
Kim, Ko, Kim, & Koh, 2008	2008	x						x
Neuby & Rudin, 2008	2008	x						x
Ustundag & Tanyas, 2009	2009	x						x
Quante, Meyr, & Fleischmann, 2009	2009							x
Warner, 2009	2009							x
Kumar, Swanson, & Tran, 2009	2009		x					x
Thiesse & Condea, 2009	2009							x
Tewary, et al., 2009	2009	x	x				x	
Cheung, Chu, & Du, 2009	2009				x			x
Bendavid, Lefebvre, & Fosso-wamba, 2009	2009		x				x	
Kumar, Dieveney, & Dieveney, 2009	2009		x		x			
Smith, Lee, & Gleim, 2009	2009		x				x	
Garcia-Arca & Prado-Prado, 2009	2009				x	x		
Martínez-Sala, et al., 2009	2009	x					x	
Holmström, Kajosaari, Främling, & Langius, 2009	2009							x
Mehrjerdi, 2009	2009		x				x	
Wang & Wang, 2009	2009	x			x			
Daim & Suntharasaj, 2009	2009				x			x
Johansson & Pålsson, 2009	2009	x				x		
Roh, Kunnathur, & Tarafdar, 2009	2009	x			x			
Ilic, Ng, Bowman, & Staake, 2009	2009							x
Goebel & Günther, 2009	2009				x			x
Mo, et al., 2009	2009							x
Pedroso, et al., 2009	2009			x		x		
Lin & Ho, 2009	2009			x		x		

Research	Year	Benefits / Issues	Implementation	Adoption	Review / Classification	Survey	Case study	Technical*
Slettemeås, 2009	2009	x			x			
Matalka, et al., 2009	2009	x	x		x			
Hozak & Hill, 2009	2009	x			x			
Miragliotta, et al., 2009	2009	x						x
Zhou, 2009	2009							x
Lin, 2009	2009			x		x		x
Kwok & Wu, 2009	2009		x				x	
Véronneau & Roy, 2009	2009	x					x	
Visich, Li, Khumawala, & Reyes, 2009	2009	x			x			
Kapoor, Zhou, & Piramuthu, 2009	2009	x			x			
Wamba & Chatfield, 2009	2009			x			x	
Total	99	42	20	10	29	12	24	45

*Technical papers and papers about the technical aspects of RFID are classified under this header.

APPENDIX B

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

Department of Information Systems and Operations Management
Old Choral Hall
7 Symonds Street
Auckland, New Zealand
Tel: 09 373 7599 ext. 85117

Survey Form

Your Copy

The Adoption of Radio Frequency Identification (RFID)
In New Zealand Supply Chains

Recently, Radio Frequency Identification (RFID) is being explored in supply chain management. The use of RFID in the supply chain management is an emerging technological trend that has attracted a lot of attention in the U.S., Europe, and Asia. This is largely driven by the potential benefits that RFID technology is perceived to deliver in the supply chain, particularly, supply chain visibility.

This survey is opened to any company in New Zealand in the manufacturing, primary produce, distribution/logistics, importer/exporter, service providers, RFID solution providers, and retail sectors, with some form of a supply chain. It is also opened to all academic institutions in order to capture a complete New Zealand's sentiment on the adoption of RFID.

The objectives of this survey are:

a. To find out the adoption status of the use of RFID in New Zealand supply chains.
b. To understand the views of New Zealand industry and academia on the use of RFID in the supply chain.

Please read the participant information before proceeding.

Please answer all questions.

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

Department of Information Systems and Operations Management
Old Choral Hall
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Survey Form

Return this Copy

Part A: Background Information

1. Which industry best describes your organisation?
   (Refer to Part F for industry definitions)

○ Aerospace	○ Export/Import	○ Manufacturing
○ Agriculture	○ Fishing	○ Mining
○ Biotechnology	○ Forestry	○ Retail Trade
○ Business Services	○ Government/Defence	○ Transport/Storage
○ Construction	○ Healthcare	○ Wholesale Trade
○ Education	○ Horticulture	○ ICT
○ Energy	○ Communication/Media	○ Others:

2. Select one that best describes the role of your organisation in a supply chain.

○ Manufacturers/Suppliers/Producers	○ Warehouse/Distributors/Transporters
○ Retailers	○ RFID Solution Providers/Advisors
○ Academic Institutions	○ Others:

3. Which organisation type best describes your organisation?

○ Local Multi-National Corporation	○ Overseas Multi-National Corporation
○ Large Enterprise	○ Small-Medium Enterprise
○ Public/Government Institution	○ Others:

4. Number of employees in New Zealand entity:

○ 1-10 ○ 11-20 ○ 21-50 ○ 51-100 ○ 101-200 ○ Above 200

If you are a User or potential User of RFID for supply chain management (e.g. supplier, distributor, retailer) please proceed to Part B. If you are an RFID solution provider/advisor, please proceed to Part C. If you are from an Academic institution, please proceed to Part D.

Part B: For Users

If you are a user or potential user of RFID, please complete this section.

5. Select one that best describes the status of RFID initiatives in your organisation. Please continue to question 16 if your answer is *not adopting*.

○ Adopting and using

○ Planning and testing

○ Not adopting but intend to in the next 12 months

○ Not adopting but intend to in the next 3 years

○ Not adopting and have no investment intention

6. If you are adopting/using or planning/testing RFID, select **three** primary reasons for the intention to adopt RFID, else go to question 16.

☐ Compliance to mandate (For example: from a supply chain partner)

☐ Better inventory visibility

☐ Better visibility of order fulfilment

☐ Improve Labour efficiency

☐ Asset tracking

☐ Out of stock reduction

☐ Better shelf inventory and replenishment

- ☐ Theft reduction
- ☐ Inventory reduction
- ☐ Cost reduction
- ☐ Counterfeit reduction
- ☐ Speed up order fulfilment
- ☐ Product traceability requirements
- ☐ Others: _____

7. When planning to adopt RFID, to what extent has each of the following concerns affected your decision? Please indicate the level of concerns with the scale of 1 -5 (1 means *'No Concern'* and 5 means *'Very Concerned'*).

S/N	Concerns	1	2	3	4	5
A	Investment costs would be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
F	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Difficulty with scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

8. In thinking about your existing or potential investment in RFID, what are your key concerns around further investment?

   a. Concern 1: _____
   _____
   _____

   b. Concern 2: _____
   _____
   _____

   c. Concern 3: _____
   _____
   _____

9. Please rate your level of satisfaction for the following based on the results of your RFID implementation. (1 means *'Not Satisfied'* and 5 means *'Very Satisfied'*).

S/N	**Results of Implementation**	**1**	**2**	**3**	**4**	**5**
A	Investment costs within budget	○	○	○	○	○
B	Improvement to work performance	○	○	○	○	○
C	Overall integration achievement	○	○	○	○	○
D	Standards Compatibility	○	○	○	○	○
E	Security of data meets company's requirements	○	○	○	○	○
F	Change to business processes	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Scanning accuracy at my site	○	○	○	○	○
I	Usefulness of data collected by RFID to company	○	○	○	○	○
J	Learning how to use the RFID systems	○	○	○	○	○

10. At what level is the RFID system integrated within your organisation? Please tick one or more where applicable.

- ☐ Stand alone RFID system
- ☐ Integrated with organisation IT infrastructure
- ☐ Integrated with warehouse management system
- ☐ Integrated with transport or logistics provider
- ☐ Integrated with supply chain members
- ☐ Integrated with other: _____

11. Was the RFID project outsourced?

○ Yes ○ No ○ Mixed inhouse/outsourced

12. If outsourced, how effective has the project been in reaching desired objectives?

○ Not Effective ○ Somewhat Effective ○ Very Effective ○ Not Applicable

13. How much was invested in the RFID project thus far (in NZD)?

○ Less than NZD $20,000 ○ $21K to $50K
○ $51 - $100K ○ $101K - $200K
○ $201K - $500K ○ Above $500K

14. If you already have RFID implemented but plan to further invest in RFID in the next 3 years, how much do you intend to invest?

○ Less than NZD $20,000 ○ $21K to $50K
○ $51 - $100K ○ $101K - $200K
○ $201K - $500K ○ Above $500K
○ No further investment

15. If you are not adopting, select **three** primary reasons for not adopting RFID in the supply chain. Else go to question 18.

- ☐ Lack of funding
- ☐ Lack of agreement on standards
- ☐ Lack of integration
- ☐ Lack of understanding
- ☐ Lack of expertise/knowledge
- ☐ Costs of investment
- ☐ Requirement to change business processes
- ☐ No requirement for RFID
- ☐ Others: _____

16. If you are not adopting, to what extent do you think each of the following has an impact when making the decision to adopt RFID? (1 means '*No Impact*', 3 means '*Some Impact*', and 5 means '*High Impact*'). Else go to question 18.

S/N	Results of Implementation	1	2	3	4	5
A	Investment costs would be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
G	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Difficulty with scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

17. If you are not adopting but have the intention to adopt RFID in the supply chain, how much do you intend to invest in this initiative? Else go to question 18.

- ○ Less than NZ $20,000
- ○ $21K to $50K
- ○ $51 - $100K
- ○ $101K - $200K
- ○ $201K - $500K
- ○ Above $500K
- ○ No further investment

18. What is your **perception** for each of the following when planning on an RFID project? (1 means '*Very Difficult*', 3 means '*Neutral*', and 5 means '*Very Easy*').

S/N	Item	1	2	3	4	5
A	Selecting the right project team members	○	○	○	○	○
B	Selecting the right vendors (RFID, IT)	○	○	○	○	○
C	Learning about RFID	○	○	○	○	○
D	Identifying the areas where RFID can be used	○	○	○	○	○
E	Getting resources and support for the project	○	○	○	○	○
F	Training users	○	○	○	○	○
G	Using of RFID application/device	○	○	○	○	○
H	Usefulness of the RFID application	○	○	○	○	○
I	Overall implementation	○	○	○	○	○

19. What tagging strategy is your organisation planning to deploy or has already deployed in your supply chain? You may select more than one strategy.

- ☐ Slap and ship (tag with EAN/EPC code after packing)
- ☐ Maintain separate inventory of tagged and untagged product (Piloting specific products)
- ☐ Tag at container or truck level
- ☐ Tag at pallet or case level
- ☐ Tag at item level

☐ Have not decided yet

☐ Others: _____

20. When evaluating the investment costs, to what extent is each of the following costs a concern? (1 means '*Not Concerned*', 3 means '*Somewhat Concerned*', and 5 means '*Very Concerned*').

S/N	Concerns	1	2	3	4	5
A	Costs of RFID infrastructure setup (For example: reader, wiring, server)	○	○	○	○	○
B	Cost of tag	○	○	○	○	○
C	Cost of application/system integration	○	○	○	○	○
D	Cost of change to business processes	○	○	○	○	○
E	Cost of data management	○	○	○	○	○
F	Cost of maintaining the RFID systems	○	○	○	○	○
G	Cost of upgrading existing infrastructure	○	○	○	○	○

21. At which of the following stages do you think your supply chain is at present?

○ Some sort of electronic integration between yours and your suppliers' systems at departmental level

○ Some sort of electronic integration among departments in your organisation and between your suppliers' systems at departmental level

○ Some sort of electronic communication between yours, your suppliers' and your customers' systems

22. Who do you think benefit most from RFID implementation among the supply chain members?

○ Manufacturers/Suppliers/Producers

○ Warehouse/Distributors/Transporters

○ Retailers

Part C: For RFID Solution Providers/Advisors

If you are an RFID solution provider or advisor please complete this section.

23. Please select the type of RFID solution services your organisation provides.

☐ Software application ☐ Hardware

☐ Project management ☐ Process mapping

☐ IT integration ☐ Others: _____

24. How many RFQ/I (request for quotation/information) has your organisation responded to in the last 12 months that have an RFID requirement?

○ 0-5 ○ 6-10 ○ 11-20 ○ Above 20

25. To what extent would you rate your company knowledge in the following?
(1 means '*Some Knowledge*', 3 means '*Average Knowledge*', and 5 means '*Expert*')

S/N	Skills	1	2	3	4	5
A	Electronic Product Code (EAN/EPC) compliance	○	○	○	○	○
B	Data management	○	○	○	○	○
C	RFID integration with existing systems	○	○	○	○	○
D	Business process solution with RFID	○	○	○	○	○
E	Understanding user's requirement for RFID	○	○	○	○	○
F	Physical aspects of RFID	○	○	○	○	○

26. Please select three primary reasons to implement RFID in the supply chain.

☐ Compliance to mandate (For example: from a supply chain partner)

☐ Better inventory visibility

☐ Better visibility of order fulfilment

☐ Improve Labour efficiency

- ☐ Asset tracking
- ☐ Out of stock reduction
- ☐ Better shelf inventory and replenishment
- ☐ Theft reduction
- ☐ Inventory reduction
- ☐ Cost reduction
- ☐ Counterfeit reduction
- ☐ Speed up order fulfilment
- ☐ Product traceability requirements
- ☐ Others: _____

27. To what extent has each of the following concerns been expressed by your customers when asked to implement RFID in their supply chains?
(1 means '*No Concern*' and 5 means '*Very Concerned*')

S/N	Concerns	1	2	3	4	5
A	Investment costs might be too high	○	○	○	○	○
B	There might not be much improvement to work performance	○	○	○	○	○
C	Overall integration might not be achieved	○	○	○	○	○
D	Standards might be incompatible	○	○	○	○	○
E	Security of data might not meet company's requirements	○	○	○	○	○
F	Change to business processes might be disruptive	○	○	○	○	○
G	Tags working with my products	○	○	○	○	○
H	Scanning accuracy at my site	○	○	○	○	○
I	Data collected by RFID might not be useful to the company	○	○	○	○	○
J	Employee might find it difficult to learn how to use the RFID systems	○	○	○	○	○

28. To what extent has each of the following issues been when implementing RFID for your customers?
(1 means '*Not Difficult*, 2 means '*Somewhat Difficult*', 3 means '*Very Difficult*', 4 means '*Not Applicable*')

S/N	Issues	1	2	3	4
A	Compliance or availability of standards				
B	Meeting business process requirements				
C	Integrating with existing systems				
D	Meeting customer expectations				
E	Minimising disruption to customer operations				
F	Training				
G	Accuracy of tag read-rate				
H	Managing RFID data				

29. To what extent has each of the following business functions been implemented with RFID thus far by your customers?
(1 means '*Not Implemented*', 2 means '*Some Implementation*', 3 means '*Extensive Implementation*', and 4 means '*Not Applicable*')

S/N	Functions	1	2	3	4
A	Tagged at manufacturing process				
B	Warehouse receiving and put away				
C	Warehouse picking and shipping				
D	Warehouse storage				
E	Warehouse cross-dock operation				
F	Retail receiving				
G	Retail on-shelf replenishment				
H	Product return/recall operation				

Part D: For Academic Institutions

If you are from an academic institution, please complete this section.

30. Is your institution currently offering a course/paper on the topic of RFID?

○ Yes ○ No

31. If yes, at what level is the course being offered?

☐ Certificate ☐ Under-graduate

☐ Diploma ☐ Post-graduate

32. Is there ongoing research on RFID in your institution?

○ Yes ○ No

33. If yes, to what extent has each of the following been researched?
(1 means '*Not Extensive*', 2 means '*Somewhat Extensive*', 3 means '*Very Extensive*', and 4 means '*Don't Know*')

S/N	Issues	1	2	3	4
A	Physical aspects of RF - technical	○	○	○	○
B	Manufacturing of RFID hardware	○	○	○	○
C	RFID software application	○	○	○	○
D	RFID data management	○	○	○	○
E	RFID in the supply chain	○	○	○	○
F	RFID in the commercial	○	○	○	○
G	Privacy issues of RFID	○	○	○	○

Part E: Contact Information

Thank you for taking time to complete the survey. Your input is valuable to us. If you would like us to contact you for a further study, please give us your contact information. Your support is appreciated.

34. Your Name: _____
35. Your Role in the organisation: _____
36. Organisation name: _____
37. Contact phone number: _____
38. E-mail address: _____

Part F: Appendices

39. Definition of industry type:

Industry	**Definition**
Aerospace	Airline operations and engineering
Agriculture	Animal farming, sheep, cattle, deer, etc.
Biotechnology	Application of science and technology to living organisms.
Business services	Providing professional business services, includes technical, computer, legal, accounting, etc.
Construction	Builds, alters, repairs residential and non-residential buildings.
Education	Primary, secondary, and tertiary education services.
Energy	Producing and distributing electricity, gas and petroleum-based energy products.
Export/Import	Exporting, importing and overseas cargo.
Fishing	Fish farming and harvesting.
Forestry	Harvesting forest, planting, replanting.
Government/Defence	Central, local government and defence forces.
Healthcare	Pharmaceutical and health services.
Horticulture	Crop growing, fruits and vegetables.
Communication	Producing and selling of communication product and services.
Manufacturing	Producing goods from raw materials or assembling products from components, includes alcohol and tobacco.
Mining	Extracting of raw materials.
Retail Trade	Selling household and personal goods and services, includes supermarket, bookshops, restaurants, hotels, motels, repairers of household equipments and motor vehicles.
Transport/Storage	Air, ocean, land transport services. Warehousing and distribution.
Wholesale Trade	Selling and reselling of new or used goods to retailers, businesses or institutional.
Others	Other type of businesses not listed in the above.

APPENDIX C

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

Department of Information Systems and Operations Management
Owen G Glenn Building
12 Grafton Road, Room 4107
Auckland, New Zealand
Tel: 09 373 7599

Interview Protocol and Guidelines

Guideline

Part A: Schedule

S/No	Agenda	Time
1	Provide research background to participant	3
2	Collect general information and content from participant	6
3	Commence interview using guideline below	17
4	Sum up the interview by providing a summary	1
		27 min

*Participants are asked to complete a questionnaire (Appendix D) prior to the interview. The results are studied before the conduct of the interview so that further questions raised from the questionnaire could be asked.

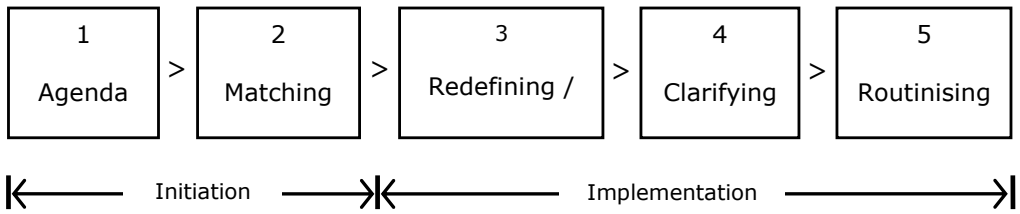
Step 1. Greet and introduce myself to the interviewee. Provide a summary of the research background and objectives to the interviewee (Appendix E).

Step 2. Describe the procedure to the interviewee and get his or her content (Appendix E).

Step 3. Follow the interview guidelines, part B below, to begin the interview.

Step 4. Give a summary of the interview by stating keys point to the interviewee for his or her confirmation. Follow up on the questionnaire (Appendix D) with the interviewee for confirmation. Close the interview and thank the interviewee.

Part B: Interview Guidelines



1. Agenda Setting – Identifying and prioritising needs and problems.

   - How RFID came about? What caused the idea of using RFID?
   - Who identified RFID as a potential solution?
   - What come first: RFID innovation or problems that need a solution?
   - What are the problems/issues identified?
   - How long was this stage?

2. Matching – Fitting problems with innovation (feasibility study).

   - What activities were involved after identifying the problems and RFID as the possible solution?
   - What were the benefits of RFID?
   - Was RFID a match or mis-match with the problems?
   - What were the primary driving points to trial RFID before the decision of adoption was made?

3. Redefining / Restructuring

   - What specific changes were made to accommodate RFID?
   - What have changed to the structure of the organisation? E.g. new department, process, office, employee, suppliers.
   - How was the project team formed?
   - To what degree will using RFID change the current processes?

4. Clarifying – When innovation is put into more widespread use in an organisation (diffusion).

    - How does it work?
    - What does it do?
    - Who is affected by the innovation?

5. Routinising – When innovation becomes incorporated into the regular activities of the organisation (infusion).

    - How fit was the innovation with organisation?
    - What is the degree of re-invention?
    - What is the involvement of the local champion in this area?

6. Termination – Not adopting at some point

    - What were the reasons for not adopting?
    - Who made this decision?
    - If not adopting after trial, was the trial and time spent trying worth it? (dissonance)

Part C: Post-Interview

1. Mark all notes with interviewees' assigned codes and file the notes in the same location. Example, A to D has been assigned to suppliers, E to H assigned to distributers, and I to K assigned to retailers.

2. Organise the notes and transfer to MS Words document format within 1 day from the interview.

3. Upload the notes to NVivo.

4. Scan and file all documents together with other electronics communications with the interviewees.

APPENDIX D

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

Department of Information Systems and Operations Management

Questionnaires for Interview

Please indicate the extent of agree and disagree each statement is in describing your interaction with RFID

SN	Question	1 (Strongly Disagree)	2	3 (Disagree)	4	5 (Agree)	6	7 (Strongly Agree)	Category	Sub-Category
1	To what extent is your company planning or using RFID	☐ Not Extensive	☐	☐	☐ Extensive	☐	☐	☐ Very Extensive	Current Use	-
2	To what extent does your company intend to increase future usage of RFID	☐ Not Extensive	☐	☐	☐ Extensive	☐	☐	☐ Very Extensive	Future Use	-
3	The use of RFID is compatible with existing systems and standards	☐	☐	☐	☐	☐	☐	☐	Compatibility	Technology
4	The use of RFID is compatible with company's existing values/beliefs	☐	☐	☐	☐	☐	☐	☐	Compatibility	Organisation
5	The use of RFID is compatible with our partners'/suppliers'/customers' systems and standards	☐	☐	☐	☐	☐	☐	☐	Compatibility	Environment
6	Using the RFID system improves the data accuracy	☐	☐	☐	☐	☐	☐	☐	Relative Advantage	Technology
7	Using the RFID system benefits our organisation	☐	☐	☐	☐	☐	☐	☐	Relative Advantage	Organisation

8	Using the RFID system improves the quality of information sharing among partners/suppliers/customers	☐	☐	☐	☐	☐	☐	☐	Relative Advantage	Environment
9	Our company will use RFID to conform to technological standards requirement	☐	☐	☐	☐	☐	☐	☐	Pressure	Technology
10	Our company will use RFID to conform to a requirement	☐	☐	☐	☐	☐	☐	☐	Pressure	Organisation
11	Our company will use RFID if requested by important business partners	☐	☐	☐	☐	☐	☐	☐	Pressure	Environment
12	RFID technology improves supply chain visibility and quality of work, thus we should use RFID in our supply chain	☐	☐	☐	☐	☐	☐	☐	Subjective Norm	Technology
13	People who influence decision making in our company think that we should use RFID to improve work performance	☐	☐	☐	☐	☐	☐	☐	Subjective Norm	Organisation
14	Our partners/suppliers/customers think that our company should use RFID	☐	☐	☐	☐	☐	☐	☐	Subjective Norm	Environment
15	RFID technology allows our company to try out various RFID scenarios for implementation	☐	☐	☐	☐	☐	☐	☐	Facilitating	Technology
16	Our company has the expertise or knowledge to implement RFID	☐	☐	☐	☐	☐	☐	☐	Facilitating	Organisation
17	There is experienced RFID service provider to implement RFID for our company	☐	☐	☐	☐	☐	☐	☐	Facilitating	Environment
18	RFID technology is still not reliable for our company to implement the technology	☐	☐	☐	☐	☐	☐	☐	Readiness	Technology
19	Our company infrastructure is not ready for RFID implementation	☐	☐	☐	☐	☐	☐	☐	Readiness	Organisation
20	Our partners/suppliers/customers are not ready to implement RFID	☐	☐	☐	☐	☐	☐	☐	Readiness	Environment

21	We have privacy concerns regarding some technical aspects of RFID	☐	☐	☐	☐	☐	☐	☐	Privacy	Technology
22	Using RFID does not conform to our company's privacy policy	☐	☐	☐	☐	☐	☐	☐	Privacy	Organisation
23	Using RFID does not conform to our partners'/suppliers'/customers' privacy standards or policies	☐	☐	☐	☐	☐	☐	☐	Privacy	Environment

APPENDIX E

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

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Tel: 09 373 7599

PARTICIPANT INFORMATION SHEET INTERVIEW

Title: The Adoption of Radio Frequency Identification in New Zealand Supply Chains

My name is Chin Boo Soon. I am a PhD candidate at The University of Auckland conducting research on the adoption of radio frequency identification (RFID) in New Zealand supply chains. There are two parts to the research. The first part is an exploratory survey using questionnaires as a data collection method which has already been completed in November 2007. This is the second part of the research. It is a qualitative study where different target groups are selected for interviews.

You are invited to participate in this interview. It takes approximately 25 minutes to complete the interview and questionnaire. You may withdraw from the interview at any time. After the interview, you may withdraw your information within two weeks of the interview date. *All information you provide will be anonymised and no names will be mentioned in relation to the result. All information of any form, including electronic e-mails, will be kept in a secure location on the University's premises. No identifiable information will be given to a third party.*

The objectives of the interview are:

(1) To find out the factors affecting the adoption of RFID in NZ's supply chains.
(2) To understand the decision factors in adopting and diffusing RFID technology in NZ's supply chains.

Please complete the content form provided. Thank you very much for your time and help in making this study possible. If you have any queries and wish to know more, or please contact me at:

Researcher: Chin Boo Soon
Department of Information Systems and Operations Management
The University of Auckland Private Bag 92019
Auckland. Tel: 09 373 7599

My supervisor is: Dr. Jairo Gutierrez
Department of Information Systems and Operations Management
The University of Auckland Private Bag 92019
Auckland. Tel: 09 373 7599 ext. 6851

The Head of Department is: Professor Don Sheridan
Department of Information Systems and Operations Management
The University of Auckland Private Bag 92019
Auckland. Tel: 09 373 7599 ext. 5328

For any queries regarding ethical concerns please contact:

The Chair, The University of Auckland Human Participants Ethics Committee,
The University of Auckland, Room 005, Alfred Nathan House, 24 Princes Street, Office of the Vice Chancellor, Private Bag 92019, Auckland. Tel: 09 373 7599 ext. 7830

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE on 11/07/2007 for a period of three years, from 10/07/2010 Reference 2007/187

THE UNIVERSITY OF AUCKLAND
BUSINESS SCHOOL

Department of Information Systems and Operations Management
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Auckland, New Zealand.
Tel: 09 373 7599

CONSENT FORM

INTERVIEW

THIS CONSENT FORM WILL BE HELD FOR A PERIOD OF SIX YEARS

Title: The Adoption of Radio Frequency Identification in New Zealand Supply Chains

Researcher: Chin Boo Soon

I have read the participant information and have understood the purpose of this research project.

- ☐ I may withdraw the information I have provided within two weeks of the interview date.
- ☐ I agree to take part in the interview.

*Please tick if you agree to take part.

Signed:

Name:
(please print clearly)

Date:

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPATNS ETHICS COMMITTEE on 11/07/2007 for a period of three years, from 10/07/2010 Reference 2007/187

REFERENCES

ABIResearch. (2006). RFID End-User Survey. *ABIResearch* Retrieved November 13, 2007, from http://www.abiresearch.com

Agarwal, R. (2000). Individual Acceptance of Information Technologies. In R. W. Zmud (Ed.), *Framing the Domains of IT Management: Projecting the Future Through the Past* (pp. 85-104). Cincinnati: Pinnaflex.

Agarwal, R., & Prasad, J. (1997). The Role of Innovation Characteristics and Perceived Voluntariness in the Acceptance of Information Technology. *Decision Sciences, 28*(3), 557-582.

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. In J. Kuhl & J. Beckmann (Eds.), *Action Control: From Cognition to Behavior* (pp. 11-39). New York: Springer.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.

Al-Qirim, N. (2005). An Empirical Investigation of an E-Commerce Adoption-Capability Model in Small Business in New Zealand. *Electronic Markets, 15*(4), 418-437.

Allen, L. G. (1991). Automatic Identification: How Do You Choose It & Where Do You Use It? *Automation, 38*(7), 30-33.

Alu, A., Sapia, C., Toscano, A., & Vegni, L. (2006). Radio Frequency Animal Identification: Electromagnetic analysis and experimental evaluation of the transponder-gate system. *International Journal of Radio Frequency Technology and Applications, 1*(1), 90-106.

Amini, M., Otondo, R., Janz, B., & Pitts, M. (2007). Simulation Modeling and Analysis: A Collateral Application and Exposition of RFID Technology. *Production and Operations Management, 16*(5), 586.

Amoako-Gyampah, K., & Salam, A. F. (2003). An Extension of the Technology Acceptance Model in an ERP Implementation Environment. *Information & Management, 41*, 731-745.

Angeles, R. (2005). RFID Technologies: Supply-Chain Applications and Implementation Issues. *Information Systems Management, 22*(1), 51-65.

Anonymous. (1993). Bar code technology increases efficiency for off-site records storage firm. *Managing Office Technology, 38*(11), 65-67.

Anonymous. (2003a). Meeting the Retail RFID Mandate: A discussion of the issues facing CPG companies. *A T Kearney* Retrieved January 17, 2007

Anonymous. (2003b). Tesco Deploys Class 1 EPC Tag. *RFIDJournal* Retrieved January 17, 2007, from http://www.rfidjournal.com

Anonymous. (2003c). Wal-Mart Draws Line in the Sand. *RFIDJournal* Retrieved January 17, 2007, from http://www.rfidjournal.com

Anonymous. (2004a). Active RFID System Frequencies. Retrieved December 21, 2007, from http://www.idtechex.com

Anonymous. (2004b). Target Issues RFID Mandate. *RFIDJournal* Retrieved January 17, 2007, from http://www.rfidjournal.com

Anonymous. (2005). RFID: From farm gate to restaurant plate. *iStart Magazine* Retrieved April 13, 2007, from http://www.istart.co.nz

Anonymous. (2006). RFID Picks Up the Pace. *iStart Magazine* Retrieved April 3, 2007, from http://www.istart.co.nz

Anonymous. (2007a). Automatic Identification and Data Capture Technologies - An overview. Retrieved January, 29, 2007, from http://www.aimglobal.org/technologies/aidc_overview.asp

Anonymous. (2007b). *Electromagnetic compatibility and Radio spectrum Matters (ERM)*: European Telecommunications Standards Institution.

Anonymous. (2007c). *An Engineering Discussion Paper on Spectrum Allocations for Short Range Devices*: New Zealand Ministry of Economic Development.

Anonymous. (2008a). EPC/RFID Arrives! New Zealand's First Major Roll-out. *SCAN*, 4-7.

Anonymous. (2008b). Health board shelves patient RFID trial. *The Dominion Post* Retrieved Feburary 26th, 2010, from http://www.stuff.co.nz/technology/638715

Anonymous. (2009). Overseas Merchandise Trade: October 2009. *New Zealand Statistics* Retrieved Feburary 26th, 2010, from http://www.stats.govt.nz/browse_for_stats/imports_and_exports/goods/overseasmerchandisetrade_hotpoct09.aspx

Anonymous. (2010a). National State of the Environment Reporting. *Ministry for the Environment* Retrieved Feburary 27th, 2010, from http://www.mfe.govt.nz/issues/land/land-cover-dbase/

Anonymous. (2010b). RFID Pet Door. *Access Control* Retrieved Feburary 26th, 2010

Anonymous. (2010c). What Technology will NAIT Use? *National Animal Identification & Tracing* Retrieved Feburary 27th, 2010, from http://www.nait.org.nz/nait_FAQ.cfm?#s96

Asif, Z., & Mandviwalla, M. (2005). Integrating the supply chain with RFID: A technical and business analysis. *Communications of the AIS, 15*(24), pp. 393-426.

Atkinson, W. (2004). Web-Based RFID: Hype or Glimpse of the Future? *Apparel, 45*(6), 24-28.

Attaran, M. (2007). RFID: an enabler of supply chain operations. *Supply Chain Management, 12*(4), 249.

Bacheldor, B. (2007). ACMA Renews GS1 Australia's UHF RFID License. *RFIDJournal* Retrieved July 29, 2007, from http://www.rfidjournal.com

Bahl, P., & Padmanabhan, V. N. (2000). *RADAR: An in-building user location and tracking system.* Paper presented at the Proceedings of the IEEE Infocom 2000.

Bandura, A. (1982). Self-Efficacy Mechanism in Human Agency. *American Psychologist, 37*(2), 122-147.

Barratt, M., & Oke, A. (2007). Antecedents of Supply Chain Visibility in Retail Supply Chains: A Resource-based Theory Perspective. *Journal of Operations Management, 25*, 1217-1233.

Barry, J. (2006). The Financial Supply Chain. In J. L. Cavinato, A. L. Flynn & R. G. Kauffman (Eds.), *The Supply Management Handbook* (7th ed., pp. 245-261). NY: McGraw-Hill.

Barthel, H. (2006). *Regulatory Status for Using RFID in the UHF Spectrum*. Brussels: GS1.

Barthel, H. (2007). *Regulatory Status for Using RFID in the UHF Spectrum*. Brussels: GS1.

Baskerville, R. L., & Wood-Harper, A. T. (Eds.). (2002). *A Critical Perspective on Action Research as a Method for Information Systems Research*. London: Sage Publications.

Basnet, C., Childerhouse, P., Foulds, L. R., & Martin, V. (2006). Sustaining Supply Chain Management in New Zealand. *International Journal of Logistics Systems and Management, 2*(3), 217-229.

Basnet, C., Corner, J., Wisner, J., & Tan, K.-C. (2003). Benchmarking Supply Chain Management Practice in New Zealand. *Supply Chain Management: An International Journal, 8*(1), 57-64.

Bednarz, A. (2004). RFID joins wireless lineup at UPS. *Network World, 21*(38), 8.

Bell, S. (2004a). Kiwi firms radio in RFID progress. *Computerworld* Retrieved November 16, 2006, from http://www.computerworld.co.nz

Bell, S. (2004b). NZ needs to start on RFID. *Computerworld* Retrieved November 16, 2006, from http://www.computerworld.co.nz

Bell, S. (2005). The Warehouse chooses IBM for RFID trial. *Computerworld* Retrieved November 16, 2006, from http://www.computerworld.co.nz

Bell, S. (2006). Wireless technology mooted to relieve Auckland traffic. *Computerworld* Retrieved November 16, 2006, from http://www.computerworld.co.nz

Benbasat, I., Dexter, A. S., & Todd, P. (1986). An Experimental Program Investigating Color-enhanced and Graphical Information Presentation: An Integration of the Findings. *Communications of the ACM, 29*(11), 1094-1105.

Bendavid, Y., Lefebvre, L., & Fosso-wamba, S. (2009). Key performance indicators for the evaluation of RFID-enabled B-to-B e-commerce applications: the case of a five-layer supply chain. *Information Systems and eBusiness Management, 7*(1), 1.

Bendoly, E., Citurs, A., & Konsynski, B. (2007). Internal Infrastructural Impacts on RFID Perceptions and Commitment: Knowledge, Operational Procedures, and Information-Processing Standards. *Decision Sciences, 38*(3), 423.

Bhuptani, M., & Moradpour, S. (2005). *RFID Field Guide - Deploying Radio Frequency Identification Systems*. NJ: Prentice Hall.

Birou, L. (2006). Relational Supply Chain: From Arm's Length to Alliances and Joint Ventures. In J. L. Cavinato, A. L. Flynn & R. G. Kauffman (Eds.), *The Supply Management Handbook* (7th ed., pp. 289-309). NY: McGraw-Hill.

Boeck, H., & Wamba, S. F. (2008). RFID and buyer-seller relationships in the retail supply chain. *International Journal of Retail & Distribution Management, 36*(6), 433.

Bottani, E., & Rizzi, A. (2008). Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. *International journal of Production Economics, 112*(2), 548.

Brown, S. A., Massey, A. P., Montoya-Weiss, M. M., & Burkman, J. R. (2002). Do I really have to? User acceptance of mandated technology. *European Journal of Information Systems, 11*(4), 283-295.

Burkett, T. (1993). Bar code implementation. *Quality, 32*(3), 28.

Burt, D. N., Dobler, D. W., & Starling, S. L. (2003). *World Class Supply Management*^{SM} *- The Key to Supply Chain Management* (7th ed.). NY: McGraw-Hill.

Butner, K. (2006). The GMA 2005 Logistics Survey. *IBM Global Business Services* Retrieved November 13, 2007, from http://www.ibm.com

Byrne, P. M., & Golden, R. (1994). Transporting goods Down Under. *Transportation & Distribution, 35*(12), 53-59.

Cannon, A. R., Reyes, P. M., Frazier, G. V., & Prater, E. L. (2008). RFID in the Contemporary Supply Chain: Multiple Perspectives on its Benefits and Risks. *International Journal of Operations & Production Management, 28*(5), 433-454.

Carter, J. R., & Ragatz, G. L. (1991). Supplier Bar Codes: Closing the EDI Loop. *International Journal of Purchasing and Materials Management, 27*(3), 19.

Cavinato, J. L. (2006). Physical Supply Chain Design and Linkages. In J. L. Cavinato, A. E. Flynn & R. G. Kauffman (Eds.), *The Supply Management Handbook* (7th ed., pp. 235-243). NY: McGraw-Hill.

Cavinato, J. L., Flynn, A. E., & Kauffman, R. G. (Eds.). (2006). *The Supply Management Handbook* (7th ed.). NY: McGraw-Hill.

Chang, S., Hung, S. Y., Yen, D. C., & Chen, Y. J. (2008). The Determinants of RFID Adoption in the Logistics Industry - A Supply Chain Management Perspective. *Communications of the AIS, 23*(12), 197-218.

Chao, C. C., Yang, J. M., & Jen, W. Y. (2007). Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. *Technovation, 27*(5), 268.

Chau, P. Y. K., & Hui, K. L. (2001). Determinants of Small Business EDI Adoption: An Empirical Investigation. [Online]. *Journal of Organizational Computing and Eletronic Commerce, 11*(4), 229-252.

Chengalur-Smith, I., & Duchessi, P. (1999). The Initiation and Adoption of Client-Server Technology in Organizations. *Information & Management, 35*, 77-88.

Cheung, W., Chu, S., & Du, T. (2009). A technology roadmap for RFID adoption in supply chains. *International Journal of Electronic Business, 7*(1), 44.

Chin, W. W., & Gopal, A. (1995). Adoption intentions in GSS: Relative importance of beliefs. *Data Base Advance, 26*(2), 42-64.

Chow, H. K. H., Choy, K. L., Lee, W. B., & Chan, F. T. S. (2007). Integration of web-based and RFID technology in visualizing logistics operations - a case study. *Supply Chain Management, 12*(3), 221.

Christensen, C. M., Anthony, S. D., & Roth, E. A. (2004). *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*. Boston: Harvard Business School Press.

Chua, W. F. (1986). Radical developments in accounting thought. *The Accounting Review, 61*(4), 601-632.

Chuang, M. L., & Shaw, W. H. (2008). An empirical study of enterprise resource management systems implementation. *Business Process Management Journal, 14*(5), 675.

Chwelos, P., Benbasat, I., & Dexter, A. S. (2001). Research Report: Empirical Test of an EDI Adoption Model. *Information Systems Research, 12*(3), 304-321.

Clarke, R. (1994). *EDI Adoption and Usage in Australian Government Agencies 1989-94.* Paper presented at the 5th World Congress of EDI Users, Brighton: UK.

Clements, M. D., Lazo, R. M., & Martin, S. K. (2008). Relationship Connectors in NZ Fresh Produce Supply Chains. *British Food Journal, 110*(4/5), 346-360.

Collins, J. (2004a). Albertsons Annouces Mandate. *RFIDJournal* Retrieved March 3, 2007, from http://www.rfidjournal.com

Collins, J. (2004b). New Two-Frequency RFID System. *RFIDJournal* Retrieved April 2, 2007, from http://www.rfidjournal.com

Collins, J. (2005). Test Detect RFID-Radar Interference. Retrieved December 21, 2007, from http://www.rfidjournal.com

Connolly, C. (2007). Sensor trends in processing and packaging of foods and pharmaceuticals. *Sensor Review, 27*(2), 103.

Cooper, R. B., & Zmud, R. W. (1990). Information Technology Implementation Research: A Technology Diffusion Approach. *Management Science, 36*(2), 123-139.

Craig, D., & Tinaikar, R. (2006). Divide and conquer: Rethinking IT strategy. [Online]. *McKinsey on IT*(Fall), 5-13.

Crazier, J., Jensen, A., & Dave, D. (2008). The Impact of Consumer Perceptions of Information Privacy and Security Risks on the Adoption of Residual RFID Technologies. *Communications of the Association for Information Systems, 23*, 14.

Culnan, M. J. (2000). Protecting Privacy Online: Is Self-Regulation Working? *Journal of Public Policy & Marketing, 19*(1), 20-26.

D'Mello, S., Mathews, E., McCauley, L., & Markham, J. (2008). Impact of Position and Orientation of RFID Tags on Real Time Asset Tracking in a Supply Chain. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 1.

Daim, T., & Suntharasaj, P. (2009). Technology diffusion: forecasting with bibliometric analysis and Bass model. *Foresight : the Journal of Futures Studies, Strategic Thinking and Policy, 11*(3), 45-55.

Datta, S., Granger, C., Barari, M., & Gibbs, T. (2007). Management of supply chain: an alternative modelling technique for forecasting. *The Journal of the Operational Research Society, 58*(11), 1459.

Daugherty, P. J., Germain, R., & Dröge, C. (1995). Predicting EDI Technology Adoption in Logistics Management: The Influence of Context and Structure. *Logistics and Transportation Review, 31*(4), 309-324.

Davenport, T. H., & Brooks, J. D. (2004). Enterprise systems and the supply chain. *Journal of Enterprise Information Management, 17*(1), 8-19.

Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly, 13*(3), 319.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science, 35*(8), 982-1003.

Delen, D., Hardgrave, B., & Sharda, R. (2007). RFID for Better Supply-Chain Management through Enhanced Information Visibility. *Production and Operations Management, 16*(5), 613.

Dietz, C., Lemond, E., Moffatt, M., & Pak, S. (2006). Short-Range Wireless: A Future Disruptive Technology. *Interdisciplinary Telecommunications Program at The University of Colorado at Boulder* Retrieved March 17, 2007, from http://drachma.colorado.edu/dspace/handle/123456789/179

Edwards, J. (2008a). Governments Influence RFID Adoption. *RFIDJournal* Retrieved January 29, 2008, from http://www.rfidjournal.com

Edwards, J. (2008b). RFID Is a Winner in the Sports Arena. *RFIDJournal* Retrieved April 26, 2008, from http://www.rfidjournal.com

Eeden, H. v. (2004). Europe Needs New RFID Regulations. *RFIDJournal* Retrieved December 21, 2007, from http://www.rfidjournal.com

Ein-Dor, P., & Segev, E. (1978). Organizational Context and The Success of Management Information Systems. *Management Science, 24*(10), 1064-1077.

Ekman, S. (1992). Bar Coding Fixed Asset Inventories. *Management Accounting, 74*(6), 58.

Elmes, G. (2005). Yakka Apparel in NZ RFID first. *iStart Magazine* Retrieved September 13, 2007, from http://www.istart.co.nz

Engels, D. W., & Sarma, S. E. (2005). *Standardization Requirements within the RFID Class Structure Framework*. MA: Auto-ID Labs.

Enyinda, C., & Szmerekovsky, J. (2008). Sense and Respond Supply Chain: A Prescription for Mitigating Vulnerability in the U.S. Pharmaceutical Value Chain. *Journal of Global Business Issues, 2*(2), 95.

EPCglobal. (2004). The EPCglobal Network: Overview of Design, Benefits, & Security. *EPCglobal* Retrieved December 21, 2007, from http://www.epcglobalus.org

EPCglobal. (2005a). EPC Generation 1 Tag Data Standards Version 1.1 Rev.1.27. *EPCglobal* Retrieved December 21, 2007, from http://www.epcglobalus.org

EPCglobal. (2005b). Guidelines on EPC for Consumer Products. *EPCglobal* Retrieved November, 17, 2006, from http://www.epcglobalinc.org/public/ppsc_guide/

Erickson, G. S., & Kelly, E. P. (2007). Building competitive advantage with radio frequency identification tags. *Competitiveness Review, 17*(1/2), 37.

Fernie, J. (2004). Relationships in the supply chain. In J. Fernie & L. Sparks (Eds.), *Logistics and Retail Management* (2nd ed., pp. 26-47). London: Kogan Page.

Fink, R., Gillett, J., & Grzeskiewicz, G. (2007). Will RFID Change Inventory Assumptions? *Strategic Finance, 89*(4), 34.

Finkenzeller, K. (2003). *RFID Handbook - Fundamentals and Applications in Contactless Smart Cards and Identification* (2nd ed.). Chichester: Wiley.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. MA: Addison-Wesley.

Fleisch, E. (2001). *Business Perspectives on Ubiquitous Computing* (M-Lab Working Paper No. 4). St Gallen: University of St Gallen.

Frankel, E. G. (1990). *Management of Technological Change*. MA: Kluwer Academic.

Friedlos, D. (2008a). Air New Zealand Readies for RFID-enabled Boarding Passes. *RFIDJournal* Retrieved Feburary 26th, 2010

Friedlos, D. (2008b). New Zealand Kiwifruit Processor Finds ROI. *RFIDJournal* Retrieved June 5, 2008, from http://www.rfidjournal.com

Gallivan, M. J. (2001). Organizational Adoption and Assimilation of Complex Technological Innovations: Development and Application of a New Framework. *The DATA BASE for Advances in Information Systems, 32*(3), 51-85.

Garcia-Arca, J., & Prado-Prado, J. (2009). Packaging as AIDS for implementing Information and Communications Technologies (ICTs): adoption in the Spanish food sector. *International Journal of Manufacturing Technology and Management, 16*(3), 250.

Gatignon, H., & Robertson, T. S. (1989). Technology Diffusion: An Empirical Test of Competitive Effects. *Journal of Marketing, 53*(Jan), 35-49.

Gaukler, G. M., Seifert, R. W., & Hausman, W. H. (2007). Item-Level RFID in the Retail Supply Chain. *Production and Operations Management, 16*(1), 65.

Gessner, G. H., Volonino, L., & Fish, L. A. (2007). One-Up, One-Back ERM in the Food Supply Chain. *Information Systems Management, 24*(3), 213.

Giannakis, M., Croom, S., & Slack, N. (2004). Supply Chain Paradigms. In S. New & R. Westbrook (Eds.), *Understanding Supply Chain - Concepts, Critiques & Futures*. NY: Oxford University Press.

Goebel, C., & Günther, O. (2009). Benchmarking RFID profitability in complex retail distribution systems. *Electronic Markets, 19*(2/3), 103.

Good, N., Han, J., Miles, E., Molnar, D., Mulligan, D., Quilter, L., et al. (2004). *Radio Frequency ID and Privacy with Information Goods*. Paper presented at the WPES'04.

Goodhue, D. L. (1995). Understanding User Evaluations of Information Systems. *Management Science, 41*(12), 1827-1844.

Goodhue, D. L., & Thompson, R. L. (1995). Task-Technology Fit and Individual Performance. *MIS Quarterly, 19*(2), 213-236.

Grasso, J. (2004). The EPCglobal Network. *EPCglobal* Retrieved December 21, 2007, from http://www.epcglobalus.org

Hall, R. H. (1982). *Organizations: Structure and Process*. NJ: Prentice-Hall.

Harrison, D. A., Mykytyn-Jr, P. P., & Riemenschneider, C. K. (1997). Executive Decisions About Adoption of Information Technology in Small Business: Theory and Empirical Tests. [Online]. *Information Systems Research, 8*(2), 171-195.

Harvey, L. J., & Myers, M. D. (Eds.). (2002). *Scholarship and Practice: the Contribution of Ethnographic Research Methods to Bridging the Gap*. London: Sage Publications.

Heese, H. S. (2007). Inventory Record Inaccuracy, Double Marginalization, and RFID Adoption. *Production and Operations Management, 16*(5), 542.

Heinen, M. G., Coyle, G. A., & Hamilton, A. V. (2003). Barcoding makes its mark on daily practice. [Online]. *Nursing Management, Oct 2003*, 18-20.

Hightower, J., Vakili, C., Borriello, G., & Want, R. (2001). Design and Calibration of the SpotON Ad-Hoc Location Sensing System. *University of Washington* Retrieved April 26, 2008, from http://seattle.intel-research.net/people/jhightower//pubs/hightower2001design/hightower2001design.pdf

Hines, T. (1994). *Supply Chain Strategies - Customer-driven and Customer-focused*. MA: Elsevier.

Hingley, M., Taylor, S., & Ellis, C. (2007). Radio frequency identification tagging. *International Journal of Retail & Distribution Management, 35*(10), 803.

Holmström, J., Kajosaari, R., Främling, K., & Langius, E. (2009). Roadmap to tracking based business and intelligent products. *Computers in Industry, 60*(3), 229.

Hozak, K., & Hill, J. (2009). Issues and opportunities regarding replanning and rescheduling frequencies. *International Journal of Production Research, 47*(18), 4955.

Humphreys, P. K., Lai, M. K., & Sculli, D. (2001). An Inter-organizational Information System for Supply Chain Management. *International journal of Production Economics, 70*, 245-255.

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic Data Interchange and Small Organizations: Adoption and Impact of Technology. *MIS Quarterly, 19*(4), 465-485.

Igbaria, M., Zinatelli, N., Cragg, P., & Cavaye, A. L. M. (1997). Personal Computing Acceptance Factors in Small Firms: A Structural Equation Model. *MIS Quarterly, 21*(3), 279-302.

Ilic, A., Ng, J., Bowman, P., & Staake, T. (2009). The value of RFID for RTI management. *Electronic Markets, 19*(2/3), 125.

iStart. (2006). IT Investment Intentions 2006. *iStart Magazine* Retrieved April 13, 2007, from http://www.istart.co.nz

iStart. (2007). IT Investment Intentions 2007. *iStart Magazine* Retrieved April 13, 2007, from http://www.istart.co.nz

iStart. (2008). IT Investment Intentions 2008. *iStart Magazine* Retrieved July 30th, 2009, from http://www.istart.co.nz/

Jilovec, N. (2004). *EDI, UCCnet & RFID - Synchronizing the Supply Chain*. Colorado: 29th Street Press.

Jimenez-Martinez, J., & Polo-Redondo, Y. (2004). The Influence of EDI Adoption over its Perceived Benefits. [Online]. *Technovation, 24*, 73-79.

Johansson, O., & Pålsson, H. (2009). The impact of Auto-ID on logistics performance. *Benchmarking, 16*(4), 504-522.

Jones, A. K., Dontharaju, S., Tung, S., Hawrylak, P. J., Mats, L., Hoare, R., et al. (2006). Passive active radio frequency identification tags. *International journal of Radio Frequency Technology and Applications, 1*(1), 52-73.

Jones, K. C. (2006). 2007 To See More RFID Adoption, Continuing Need For Training. *InformationWeek* Retrieved April 13, 2007, from http://www.informationweek.com

Jones, P., Clarke-Hill, C., Comfort, D., Hillier, D., & Shears, P. (2004). Radio frequency identification in retailing and privacy and public policy issues. *Management Research News, 27*(8/9).

Jones, P., Clarke-Hill, C., Hillier, D., & Comfort, D. (2005). The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK. *Marketing Intelligence & Planning, 23*(4).

Ju, T., Ju, & Sun, S. (2008). A strategic examination of Radio Frequency Identification in Supply Chain Management. *International Journal of Technology Management, 43*(4), 349.

Kapoor, G., Zhou, W., & Piramuthu, S. (2009). Challenges associated with RFID tag implementations in supply chains. *European Journal of Information Systems, 18*(6), 526.

Karkkainen, M. (2003). Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. *International Journal of Retail & Distribution Management, 31*(10), 529-536.

Katz, J. (2006). Bar Codes: Alive and Well. [Online]. *Industry Week, 255*(7), 14.

Kelepouris, T., Pramatari, K., & Doukidis, G. (2007). RFID-enabled traceability in the food supply chain. *Industrial Management + Data Systems, 107*(2), 183.

Kelly, E. P., & Erickson, G. S. (2005). RFID tags: commercial applications vs privacy rights. *Industrial Management & Data Systems, 105*(6).

Ketchen, D. J., & Hult, G. T. M. (2007a). Bridging Organizational Theory and Supply Chain Management: The Case of Best Value Supply Chains. *Journal of Operations Management, 25*, 573-580.

Ketchen, D. J., & Hult, G. T. M. (2007b). Toward Greater Integration of Insights from Organization Theory and Supply Chain Management. *Journal of Operations Management, 25*, 455-458.

Khazanchi, S., Lewis, M. W., & Boyer, K. K. (2007). Innovation-supportive Culture: The Impact of Organizational Values on Process Innovation. *Journal of Operations Management, 25*, 871-884.

Kieckhaefer, G. V., & Inderrieden, E. J. (1987). Planning Information Systems For The Growing Business. *Business, 37*(4), 18-24.

Kim, E. Y., Ko, E., Kim, H., & Koh, C. E. (2008). Comparison of benefits of radio frequency identification: Implications for business strategic performance in the U.S. and Korean retailers. *Industrial Marketing Management, 37*(7), 797.

Klein, R. (2006). Could RFID Adoption in Manufacturing Grow? *Aberdeen Group* Retrieved April 13, 2007, from http://www.aberdeen.com

Knemeyer, M. A., & Murphy, P. R. (2004). Evaluating the Performance of Third-Party Logistics Arrangements: A Relationship Marketing Perspective. *Journal of Supply Chain Management, 40*(1), 35-51.

Kommareddi, S. (2005). Making Sense of Data. *Chain Store Age, 81*(9), 60.

Kondratova, I. (2003). *Voice and multimodal access to AEC project information.* Paper presented at the The 10th ISPE International Conference on Concurrent Engineering: The Vision for Future Generations in Research and Applications, Portugal.

Koo, C., Lee, S., Shao, D., Koh, C. E., & Jo, G. (2007). *The Likelihood of RFID (Radio Frequency Identification) Technology Initiation: The Exploratory Examination*. Paper presented at the IRMA International Conference.

Krotov, V., & Junglas, I. (2008). RFID as a Disruptive Innovation. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(2), 44.

Kuan, K. K. Y., & Chau, P. Y. K. (2001). A Perception-based Model for EDI Adoption in Small Businesses using a Technology-Organization-Environment Framework. *Information & Management, 38*, 507-521.

Kumar, S. (2007). Connective technology as a strategic tool for building effective supply chain. *International Journal of Manufacturing Technology and Management, 10*(1), 41.

Kumar, S., Dieveney, E., & Dieveney, A. (2009). Reverse logistic process control measures for the pharmaceutical industry supply chain. *International Journal of Productivity and Performance Management, 58*(2), 188.

Kumar, S., Swanson, E., & Tran, T. (2009). RFID in the healthcare supply chain: usage and application. *International Journal of Health Care Quality Assurance, 22*(1), 67-81.

Kwok, S. K., & Wu, K. K. W. (2009). RFID-based intra-supply chain in textile industry. *Industrial Management + Data Systems, 109*(9), 1166.

Kwon, K., & Zmud, R. (Eds.). (1987). *Unifying the Fragmented Models of Information Systems Implementation*. New York: Wiley.

Lacharite, R. (1991). Rethinking Bar Coding: Turning Preconceptions into System Tools. *ARMA Records Management Quarterly, 25*(2), 3.

LaLonde, B. J., & Masters, J. M. (1994). Emering Logistics Strategies: Blueprints for the Next Century. *International Journal of Physical Distribution & Logistics Management, 24*(7), 35-47.

Lambert, D. M., Stock, J. R., & Ellram, L. M. (1998). *Fundamentals of Logistics Management*. Boston, MA: Irwin/McGraw-Hill.

Landt, J. (2001). Shrouds of Time. *The history of RFID* Retrieved 19 January, 2006, from http://www.aimglobal.org/technologies/rfid/resources/shrouds_of_time.pdf

Langer, N., Forman, C., Kekre, S., & Scheller-Wolf, A. (2007). Assessing the Impact of RFID on Return Center Logistics. *Interfaces, 37*(6), 501.

Lazar, L. D., & Moss, H. K. (2005). *Radio Frequency Identification Technology: An Introduction.* Paper presented at the Proceedings of the 2005 Southern Association for Information Systems Conference, Savannah.

Lee, D., & Park, J. (2008). RFID-based traceability in the supply chain. *Industrial Management + Data Systems, 108*(6), 713.

Lee, H., & Özer, Ö. (2007). Unlocking the Value of RFID. *Production and Operations Management, 16*(1), 40.

Lee, L., Fiedler, K., & Smith, J. (2008). Radio frequency identification (RFID) implementation in the service sector: A customer-facing diffusion model. *International journal of Production Economics, 112*(2), 587.

Li, S., Visich, J. K., Khumawala, B. M., & Zhang, C. (2006). Radio frequency identification technology: applications, technical challenges and strategies. *Sensor Review, 26*(3).

Li, X., & Chandra, C. (2007). Efficient knowledge integration to support a complex supply network management. *International Journal of Manufacturing Technology and Management, 10*(1), 1.

Lin, C. T., Chiu, H., & Chu, P. Y. (2005). Agility Index in the Supply Chain. *International journal of Production Economics, 100*(2006), 285-299.

Lin, C. Y., & Ho, Y. H. (2009). RFID technology adoption and supply chain performance: an empirical study in China's logistics industry. *Supply Chain Management, 14*(5), 369-378.

Lin, L. (2009). An integrated framework for the development of radio frequency identification technology in the logistics and supply chain management. *Computers & Industrial Engineering, 57*(3), 832.

Lippert, S. K., & Forman, H. (2006). A Supply Chain Study of Technology Trust and Antecedents to Technology Internalization Consequences. *International Journal of Physical Distribution & Logistics Management, 36*(4), 271-288.

Liu, X., Tang, O., & Huang, P. (2008). Dynamic pricing and ordering decision for the perishable food of the supermarket using RFID technology. *Asia Pacific Journal of Marketing and Logistics, 20*(1), 7.

Loebbecke, C. (2007). Piloting RFID Along the Supply Chain: A Case Analysis. *Electronic Markets, 17*(1), 29.

Loebbecke, C., & Huyskens, C. (2008a). A Competitive Perspective on Standard-Making: Kaufhof's RFID Project in Fashion Retailing. *Electronic Markets, 18*(1), 30-38.

Loebbecke, C., & Huyskens, C. (2008b). Item-Level RFID in the Japanese Publishing Industry: A Case Study. *Communcations of the AIS, 23*(18), 319-332.

Lundeen, E. M. (2006). Outsourcing: Challenges and Opportunities. In J. L. Cavinato, A. E. Flynn & R. G. Kauffman (Eds.), *The Supply Management Handbook* (7th ed., pp. 187-208). NY: McGraw-Hill.

Luo, Z., Yen, B., Tan, Z., & Ni, Z. (2008). Value Analysis Framework for RFID Technology Adoption in Retailers in China. *Communcations of the AIS, 23*(17), 295-318.

MAF. (2008). The Ministry of Agriculture and Forestry. *Animal Identification and Tracing* Retrieved May, 2009

Magnan, G. M., & Fawcett, S. E. (2006). Function and Form in Supply Management Organizations. In J. L. Cavinato, A. E. Flynn & R. G. Kauffman (Eds.), *The Supply Management Handbook* (7th ed., pp. 329-355). NY: McGraw-Hill.

Markus, M. L. (Ed.). (1997). *The Qualitative Difference in Information Systems Research and Practice*. London: Chapman & Hall.

Markus, M. L., & Robey, D. (1988). Information Technology and Organizational Change: Causal Structure in Theory and Research. *Management Science, 34*(5), 583-598.

Martin, P. Y., & Turner, B. A. (1986). Grounded Theory and organizational research. *The Journal of Applied Behavioral Science, 22*(2), 141-157.

Martínez-Sala, A., Egea-López, E., García-Sánchez, F., & García-Haro, J. (2009). Tracking of Returnable Packaging and Transport Units with active RFID in the grocery supply chain. *Computers in Industry, 60*(3), 161.

Mason, B. (2005). *Bar Code Scanner Demand Remains Strong* (Press Release). Massachusetts: Venture Development Corporation.

Matalka, M., Visich, J., & Li, S. (2009). Reviewing the drivers and challenges in RFID implementation in the pharmaceutical supply chain. *International Journal of Electronic Business, 7*(5), 473.

Mathieson, K. (1991). Predicting User Intentions: Comparing the Technology Acceptance Model with the Theory of Planned Behavior. [Online]. *Information Systems Research, 2*(3), 173-191.

Matta, V. A. (2008). *Predicting the Adoption of Radio Frequency Identification Systems in the Supply Chain.* Ohio University, Ohio.

May, E. L. (2003). The case for bar coding: Better information, better care and better business. [Online]. *Healthcare Executive, 18*(5), 8-13.

McEntee, C. (2009). 'Old Technology' for $23m cattle tracing scheme. *The Dominion Post* Retrieved Feburary 26th, 2010, from http://computerworld.co.nz/news.nsf/tech/2E80078E34C21EC5CC25768B006CBA36

McFarlane, D., & Sheffi, Y. (2003). Impact of Automatic Identification on Supply Chain Operations. *International Journal of Logistics Management, 14*(1), 1-17.

McGrath, J. E., Arrow, H., Gruenfeld, D. H., Hollingshead, A. B., & O'Connor, K. M. (1993). Groups, Tasks, and Technology: The Effects of Experience and Change. [Online]. *Small Group Research, 24*(3), 406-420.

Mehrjerdi, Y. Z. (2008). RFID-enabled supply chain systems with computer simulation. *Assembly Automation, 29*(2), 174.

Mehrjerdi, Y. Z. (2009). RFID-enabled supply chain systems with computer simulation. *Assembly Automation, 29*(2), 174-183.

Mehrtens, J., Cragg, P. B., & Mills, A. M. (2001). A Model of Internet Adoption by SMEs. *Information & Management, 39*, 165-176.

Mentzer, J. T., Dewitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., et al. (2001). What Is Supply Chain Management? In J. T. Mentzer (Ed.), *Supply Chain Management* (pp. 1-25). London: Sage.

Michael, K., & McCathie, L. (2005). *The Pros and Cons of RFID in Supply Chain Management.* Paper presented at the International Conference on Mobile Business, Copenhagen: Denmark.

Miller, J. (2007). Criteria for Evaluating RFID Solutions for Records and Information. *Information Management Journal, 41*(1), 50.

Miragliotta, G., Perego, A., & Tumino, A. (2009). A quantitative model for the introduction of RFId in the fast moving consumer goods supply chain. *International Journal of Operations & Production Management, 29*(10), 1049-1082.

Mo, J. P. T., Lerias, G., Wilson, F., Brown, S., Hiroyuk, S., Seitam, D., et al. (2009). Process integration for paperless delivery using EPC compliance technology. *Journal of Manufacturing Technology Management, 20*(6), 866-886.

Moch, M. K., & Morse, E. V. (1977). Size, Centralization and Organization Adoption of Innovations. *American Sociological Review, 42*, 716-725.

Moon, K. L., & Ngai, E. W. T. (2008). The adoption of RFID in fashion retailing: a business value-added framework. *Industrial Management + Data Systems, 108*(5), 596.

Moore, G. C., & Benbasat, I. (1991). Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation. [Online]. *Information Systems Research, 2*(3), 192-222.

Mullen, D., & Moore, B. (2005). Automatic Identification and Data Collection: What the future holds. In S. Garfinkel & B. Rosenberg (Eds.), *RFID Applications, Security, and Privacy* (pp. 3-13). NJ: Addison-Wesley.

Murphy-Hoye, M., Lee, L. H., & Rice, J. B. J. (2005). A Real-World Look at RFID. *Supply Chain Management Review, 9*(5), 18-21, 24-26.

Myers, M. D., & Avison, D. E. (Eds.). (2002). *An Introduction to Qualitative Research in Information Systems*. London: Sage Publications.

Neuby, B., & Rudin, E. (2008). Radio Frequency Identification: A Panacea for Governments? *Public Organization Review, 8*(4), 329.

Neufeld, D. J., Dong, L., & Higgins, C. (2007). Charismatic Leadership and User Acceptance of Information Technology. *European Journal of Information Systems, 2007*(16), 494-510.

Ni, L. M., Liu, Y. H., Lau, Y. C., & Patil, A. P. (2004). LANDMARC: Indoor Location Sensing Using Active RFID. *Wireless Networks, 10*, 701-710.

Niemeyer, A., Pak, M. H., & Ramaswamy, S. E. (2003). Smart tags for your supply chain. *The McKinsey Quarterly, 4*, 6-8.

O'Connor, M. C. (2006). DHS Testing E-Passports in San Francisco. *RFIDJournal* Retrieved April 14, 2007, from http://www.rfidjournal.com

O'Leary, D. (2008). Supporting decisions in real-time enterprises: autonomic supply chain systems. *Information Systems and eBusiness Management, 6*(3), 239.

Orlikowski, W. J. (1993). CASE Tools as Organizational Change: Investigating Incremental and Radical Changes in Systems Development. *MIS Quarterly, 17*(3), 309-340.

Orlikowski, W. J. (Ed.). (2002). *CASE Tools as Organizational Change: Investigating Incremental and Redical Changes in Systems Development*. London: Sage Publications.

Orlikowski, W. J., & Baroudi, J. J. (Eds.). (2002). *Studying Information Technology in Organizations: Research Approaches and Assumptions*. London: Sage Publications.

Pare, G., & Elam, J. J. (1997). *Using Case Study Research to Build Theories of IT Implementation.* Paper presented at the International Conference on Information Systems and Qualitative Research, Philadelphia.

Pedroso, M. C., Zwicker, R., & Souza, C. A. d. (2009). RFID Adoption: Framework and Survey in large Brazilian companies. *Industrial Management & Data Systems, 109*(7), 877-897.

Pfeffer, J. (1982). *Organizations and Organization Theory*. Boston: Pitman.

Plouffe, C. R., Hulland, J. S., & Vandenbosch, M. (2001). Research report: Richness versus persimony in modeling technology adoption decisions - Understanding merchant adoption of a smart card-based payment system *Information Systems Research, 12*(2), 208-222.

Porter, J. D., Billo, R. E., & Mickle, M. H. (2006). Effect of active interference on the performance of radio frequency identification systems. *International journal of Radio Frequency Technology and Applications, 1*(1).

Powanga, M., & Powanga, L. P. (2008). Deploying RFID in Logistics: Criteria and Best Practices and Issues. *The Business Review, Cambridge, 9*(2), 1.

Pramatari, K. (2007). Collaborative supply chain practices and evolving technological approaches. *Supply Chain Management, 12*(3), 210.

Prater, E., Frazier, G. V., & Reyes, P. M. (2005). Future impacts of RFID on e-supply chains in grocery retailing. *Supply Chain Management: An International Journal, 10*(2), 134-142.

Premkumar, G., Ramamurthy, K., & Crum, M. (1997). Determinants of EDI Adoption in the Transportation Industry. *European Journal of Information Systems, 6*, 107-121.

Premkumar, G., Ramamurthy, K., & Nilakanta, S. (1994). Implementation of Electronic Data Interchange: An Innovation Diffusion Perspective. *Journal of Management Information Systems, 11*(2), 157-186.

Quante, R., Meyr, H., & Fleischmann, M. (2009). Revenue management and demand fulfillment: matching applications, models, and software. *OR Spectrum, 31*(1), 31.

Ramamurthy, K., Premkumar, G., & Crum, M. R. (1999). Organizational and Interorganizational Determinants of EDI Diffusion and Organizational Performance: A Causal Model. *Journal of Organizational Computing and Electronic Commerce, 9*(4), 253-285.

Ramudhin, A., Paquet, M., Artiba, A., Dupré, P., Varvaro, D., & Thomson, V. (2008). A generic framework to support the selection of an RFID-based control system with application to the MRO activities of an aircraft engine manufacturer. *Production Planning & Control, 19*(2), 183.

Raymond, L. (1990). Organizational Context and Information Systems Success: A Contingency Approach. *Journal of Management Information Systems, 6*(4), 5-20.

Rekik, Y., Jemai, Z., Sahin, E., & Dallery, Y. (2007). Improving the performance of retail stores subject to execution errors: coordination versus RFID technology. *OR Spectrum, 29*(4), 597.

Riemenschneider, C. K., Harrison, D. A., & Mykytyn-Jr, P. P. (2003). Understanding IT Adoption Decisions in Small Business: Integrating Current Theories. [Online]. *Information & Management, 40*(4), 269-285.

Roberti, M. (2003). The Clock Is Ticking. *RFIDJournal* Retrieved March 9, 2007, from http://www.rfidjournal.com

Roberti, M. (2004a). New ETSI RFID Rules Move Forward. *RFIDJournal* Retrieved December 21, 2007, from http://www.rfidjournal.com

Roberti, M. (2004b). Solving the Out-of-Stock Problem. *RFIDJournal* Retrieved July 29, 2007, from http://www.rfidjournal.com

Roberti, M. (2004c). Wal-Mart Suppliers Discuss RFID. *RFIDJournal*. Retrieved from http://www.rfidjournal.com

Roberti, M. (2006a). How World Kitchen Got it Right. *RFIDJournal* Retrieved December 28, 2006, from http://www.rfidjournal.com

Roberti, M. (2006b). SmartCode Offers 5-Cent EPC Tags. *RFIDJournal* Retrieved April 26, 2008, from http://www.rfidjournal.com

Roberti, M. (2007a). Metro Pushes Pallet Tagging. *RFIDJournal* Retrieved August 18, 2007, from http://www.rfidjournal.com

Roberti, M. (2007b). RFID Delivers in the Apparel and Footwear Sector. *RFIDJournal* Retrieved November 13, 2007, from http://www.rfidjournal.com

Roberti, M. (2007c). Wal-Mart, Suppliers Affirm RFID Benefits. *RFIDJournal* Retrieved July 29, 2007, from http://www.rfidjournal.com

Robey, T. L. (1979). User Attitudes and Management Information System Use. *Academy of Management Journal, 22*(3), 527-538.

Rodríguez-Ardura, I., Meseguer-Artola, A., & Vilaseca-Requena, J. (2008). Factors Influencing the Evolution of Electronic Commerce: An Empirical Analysis in a Developed Market Economy. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(2), 18-29.

Rogers, E. M. (1995). *Diffusion of Innovations* (4th ed.). New York: The Free Press.

Roh, J. J., Kunnathur, A., & Tarafdar, M. (2009). Classification of RFID Adoption: An Expected Benefits Approach. *Information & Management, 46*(2009), 357-363.

Rundh, B. (2008). Radio frequency identification (RFID). *Marketing Intelligence & Planning, 26*(1), 97.

Rutner, S., Waller, M. A., & Mentzer, J. T. (2004). A Practical look at RFID. *Supply Chain Management Review, 8*(1), 36-41.

Sabbaghi, A., & Vaidyanathan, G. (2008). Effectiveness and Efficiency of RFID technology in Supply Chain Management: Strategic values and Challenges. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(2), 71.

Sanders, N. R. (2007). An Empirical Study of the Impact of E-business Technologies on Organizational Collaboration and Performance. *Journal of Operations Management, 25*, 1332-1347.

Sankaran, J. (2000). Freight Logistics in the New Zealand Context. *International Journal of Physical Distribution & Logistics Management, 30*(2), 145-164.

Sarma, S. (2001). *Towards the 5-cent Tag*. MA: Auto-ID Labs.

Sarma, S. (2005). A History of the EPC. In S. Garfinkel & B. Rosenberg (Eds.), *RFID Applications, Security, and Privacy* (pp. 37-55). NJ: Addison-Wesley.

Sayer, P., & Hanover, J. N. (2006). European Commission launches inquiry into RFID. *Computerworld* Retrieved May 9, 2008, from http://www.computerworld.co.nz

Schultz, R. L., & Slevin, D. P. (1975). Implementation and Organizational Validity: An Empirical Investigation. In R. L. Schultz & D. P. Slevin (Eds.), *Implementing Operations Research/Management Science* (pp. 153-182). NY: American Elsevier.

Sellitto, C., Burgess, S., & Hawking, P. (2007). Information quality attributes associated with RFID-derived benefits in the retail supply chain. *International Journal of Retail & Distribution Management, 35*(1), 69.

Sheehan, K. B., & Hoy, M. G. (2000). Dimensions of Privacy Concern Among Online Consumers. *Journal of Public Policy & Marketing, 19*(1), 62-73.

Sheffi, Y. (2004). RFID and the Innovation Cycle. *The International Journal of Logistics Management, 15*(1).

Shepard, S. (2005). *Radio Frequency Identification*. NY: McGraw-Hill.

Shih, D., Chiu, Y., Chang, S., & Yen, D. (2008). An Empirical Study of Factors Affecting RFID's Adoption in Taiwan. *Journal of Global Information Management, 16*(2), 58.

Singh, N., Lai, K.-h., & Cheng, T. C. E. (2007). Intra-Organisational Perspectives on IT-Enabled Supply Chains. *Communications of the ACM, 50*(1), 59-65.

Skilling, D., & Boven, D. (2007). *So far yet so close: Connecting New Zealand to the global economy*: The New Zealand Institute.

Slettemeås, D. (2009). RFID--the "Next Step" in Consumer-Product Relations or Orwellian Nightmare? Challenges for Research and Policy. *Journal of Consumer Policy, 32*(3), 219.

Smith, A. D. (2005). Exploring radio frequency identification technology and its impact on business systems. *Information Management & Computer Security, 13*(1), 16-28.

Smith, H., & Konsynski, B. (2003). Developments in Practice X: Radio Frequency Identification (RFID) - An Internet for Physical Objects. [Online]. *Communications of the AIS, 12*, 301-311.

Smith, J. S., Lee, L., & Gleim, M. (2009). The impact of RFID on service organizations: a service profit chain perspective. *Managing Service Quality, 19*(2), 179.

Smucker, T. (2006). *Making the GS1 Vision a Reality* (Annual Report). Brussels: GS1.

Soon, C. B., & Gutierrez, J. (2009). Recognizing RFID as a Disruptive Technology. *International Journal of Information Systems and Supply Chain Management, 2*(1), 55-68.

Soon, C. B., & Gutierrez, J. A. (2008a). Effects of the RFID Mandate on Supply Chain Management. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 81-91.

Soon, C. B., & Gutierrez, J. A. (2008b). *Where is New Zealand at with Radio Frequency Identification in the Supply Chain? - A Survey Result.* Paper presented at the Proceedings of 2008 International Conference on Information Resources Management, Niagara Falls, Canada.

Spekman, R. E., & Sweeney-II, P. J. (2006). RFID: From concept to implementation. *International Journal of Physical Distribution & Logistics Management, 36*(10).

Sprague, L. G. (2007). Evolution of the Field of Operations Management. *Journal of Operations Management, 25*(2), 219-238.

Srivastava, S. K. (2007). Radio frequency identification technology in retail outlets: Indian scenario. *International Journal of Manufacturing Technology and Management, 10*(1), 71.

Stock, G. N., & Tatikonda, M. V. (2008). The Joint Influence of Technology Uncertainty and Interorganizational Interaction on External Technology Integration Success. *Journal of Operations Management, 26*, 65-880.

Strassner, M., & Schoch, T. (2002). *Today's Impact of Ubiquitous Computing on Business Processes.* Paper presented at the First International Conference on Pervasive Computing, Zurich, Switzerland.

Sundermann, E., & Pugh, G. (2008). RFID Techical Study: The Application of UHF RFID Technology for Animal Ear Tagging. *RFID Pathfinder Group*, 1-53.

Swann, A. (2009). Wine export growth outshines all others. *The National Business Review* Retrieved Feburary 26th, 2010

Swartz, N. (2007). NIST Issues RFID Guidelines. *Information Management Journal, 41*(4), 8.

Swedberg, C. (2006a). China Endorses ISO 18000-7 433 MHz Standard. *RFIDJournal* Retrieved July 29, 2007, from http://www.rfidjournal.com/

Swedberg, C. (2006b). New Zealand Retailer Plans RFID Pilot. *RFIDJournal* Retrieved April 14, 2007, from http://www.rfidjournal.com

Swedberg, C. (2007a). China Approves Requirements for UHF Bandwidth. *RFIDJournal* Retrieved July 29, 2007, from http://www.rfidjournal.com

Swedberg, C. (2007b). EC Spectrum Decision Expected to Boost UWB RFID Adoption. *RFIDJournal* Retrieved December 29, 2007, from http://www.rfidjournal.com

Swedberg, C. (2008a). RFID Fuels Gas Tank Sercurity. *RFIDJournal* Retrieved April 26, 2008, from http://www.rfidjournal.com

Swedberg, C. (2008b). U.S. FDA Seeks Research for Medical Device Tracking System. *RFIDJournal* Retrieved April 26, 2008, from http://www.rfidjournal.com

Szajna, B. (1996). Empirical evaluation of the revised technology acceptance model. *Management Science, 42*(1), 85-92.

Szmerekovsky, J., & Zhang, J. (2008). Coordination and adoption of item-level RFID with vendor managed inventory. *International journal of Production Economics, 114*(1), 388.

Taylor, S., & Todd, P. A. (1995). Understanding Information Technology Usage: A Test of Competing Models. *Information Systems Research, 6*(2), 144-176.

Teo, H. H., Wei, K. K., & Benbasat, I. (2003). Predicting Intention to Adopt Interorganizational Linkages: An Institutional Perspective. [Online]. *MIS Quarterly, 27*(1), 19-49.

Tewary, A., Kosalge, P., & Motwani, J. (2009). Challenges in piloting a RFID implementation: a case study of an aerospace and defence supply chain. *International Journal of Electronic Business, 7*(1), 3.

Thiesse, F., & Condea, C. (2009). RFID data sharing in supply chains: What is the value of the EPC network? *International Journal of Electronic Business, 7*(1), 21.

Thiesse, F., & Michahelles, F. (2006). An overview of EPC technology. *Sensor Review, 26*(2).

Tornatzky, L. G., & Fleischer, M. (1990). *The Processes of Technological Innovation*. MA: Lexington Books.

Tu, Y., & Piramuthu, S. (2008). Reducing False Reads in RFID-Embedded Supply Chains. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(2), 60.

Twist, D. C. (2005). The impact of radio frequency identification on supply chain facilities. *Journal of Facilities Management, 3*(3), 226-239.

Uçkun, C., Karaesmen, F., & Sava, S. (2008). Investment in improved inventory accuracy in a decentralized supply chain. *International journal of Production Economics, 113*(2), 548.

Udo, G. J., & Pickett, G. C. (1994). EDI Conversion Mandate: The Big Problem for Small Businesss. *Industrial Management, 36*(2), 6-9.

Uhrich, F., Sandner, U., Resatsch, F., Leimeister, J., & Krcmar, H. (2008). RFID in Retailing and Customer Relationship Management. *Communications of the Association for Information Systems, 23*, 13.

Ukkonen, L., Schaffrath, M., Kataja, J., Sydanheimo, L., & Kivikoski, M. (2006). Evolutionary RFID tag antenna design for paper industry applications. *International journal of Radio Frequency Technology and Applications, 1*(1), 107-122.

Ustundag, A., & Tanyas, M. (2009). The impacts of Radio Frequency Identification (RFID) technology on supply chain costs. *Transportation Research. Part E, Logistics & Transportation Review, 45*(1), 29.

Veeramani, D., Tang, J., & Gutierrez, A. (2008). A Framework for Assessing the Value of RFID Implementation by Tier-One Suppliers to Major Retailers. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 55.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

Véronneau, S., & Roy, J. (2009). RFID benefits, costs, and possibilities: The economical analysis of RFID deployment in a cruise corporation global service supply chain. *International journal of Production Economics, 122*(2), 692.

Vijayaraman, B. S., & Osyk, B. A. (2006). An empirical study of RFID implementation in the warehousing industry. *The International Journal of Logistics Management, 17*(1), 6-20.

Violino, B. (2006). APL Reaps Double Benefits From Real-Time Visibility. *RFIDJournal*. Retrieved from http://www.rfidjournal.com

Visich, J. K., Li, S., & Khumawala, B. M. (2007). Enhancing Product Recovery Value in Closed-loop Supply Chains with RFID. *Journal of Managerial Issues, 19*(3), 436.

Visich, J. K., Li, S., Khumawala, B. M., & Reyes, P. M. (2009). Empirical evidence of RFID impacts on supply chain performance. *International Journal of Operations & Production Management, 29*(12), 1290-1315.

Walker, J. (2003). What You Need To Know About RFID in 2004. *Forrester Research* Retrieved December 20, 2003, from http://www.forrester.com

Walsham, G. (Ed.). (2002). *Interpretive Case Studies in IS Research: Nature and Method*. London: Sage Publications.

Walt, D. (2005). Ask Questions To Get ROI On RFID's Impact. *InformationWeek, 1041*, 74.

Walter, E. J. (1988). Bar Code Boom Extending thru Industry. *Purchasing World, 32*(2), 39.

Walton, L. W. (1996). The ABC's of EDI: The Role of Activity-Based Costing (ABC) in Determining EDI Feasibility in Logistics Organizations. *Transportation Journal, 36*(1), 43-50.

Wamba, S., & Boeck, H. (2008). Enhancing Information Flow in a Retail Supply Chain Using RFID and the EPC Network: A Proof-of-Concept Approach. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 92.

Wamba, S., Lefebvre, L., & Bendavid, Y. (2008). Exploring the impact of RFID technology and the EPC network on mobile B2B eCommerce: A case study in the retail industry. *International journal of Production Economics, 112*(2), 614.

Wamba, S. F., & Chatfield, A. T. (2009). A Contigency Model for Creating Value from RFID Supply Chain Network Projects in Logistics and Manufacturing Environments. *European Journal of Information Systems, 2009*(18), 615-636.

Wang, L., & Wang, G. (2009). RFID-driven global supply chain and management. *International Journal of Computer Applications in Technology, 35*(1), 42.

Wang, S., Liu, S., & Wang, W. (2008). The simulated impact of RFID-enabled supply chain on pull-based inventory replenishment in TFT-LCD industry. *International journal of Production Economics, 112*(2), 570.

Warner, J. (2009). Secure RFID systems for supply chain applications. *International Journal of Electronic Business, 7*(1), 58.

Wasserman, E. (2005). Around the World in Real Time. *RFIDJournal* Retrieved August 18, 2007, from http://www.rfidjournal.com

Wasserman, E. (2007). Europe Embraces EPC - Slowly. *RFIDJournal* Retrieved December 21, 2007, from http://www.rfidjournal.com

Weinstein, R. (2005). RFID: A Technical Overview and Its Application to the Enterprise. *IT Professional Magazine, 7*(3), 27-33.

Wessel, R. (2007a). EC Floats Plan to Facilitate RFID Usage. *RFIDJournal* Retrieved January 29, 2008, from http://www.rfidjournal.com

Wessel, R. (2007b). European EPC Competence Center Expanding Its Services. *RFIDJournal* Retrieved February 10, 2007, from http://www.rfidjournal.com

Wessel, R. (2007c). European EPC Competence Center Releases UHF Tag Study. *RFIDJournal* Retrieved July 16, 2007, from http://www.rfidjournal.com

Whitaker, J., Mithas, S., & Krishna, M. S. (2007). A Field Study of RFID Deployment and Return Expectations. *Production and Operations Management, 16*(5), 599-612.

Wixom, B. H., & Watson, H. J. (2001). An Empirical Investigation of the Factors Affecting Data Warehousing Success. *MIS Quarterly, 25*(1), 17-41.

Yin, R. K. (2003). *Case Study Research Design and Methods* (3 ed. Vol. 5). CA: Sage Publications.

Zaltman, G., Duncan, R., & Holbeck, J. (1973). *Innovations and Organizations*. New York: Wiley & Sons.

Zhang, T., Ouyang, Y., & He, Y. (2008). Traceable Air Baggage Handling System Based on RFID Tags in the Airport. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), 106.

Zhou, W. (2009). RFID and item-level information visibility. *European Journal of Operational Research, 198*(1), 252.

Zhu, J., & He, Z. (2002). Diffusion, Use and Impact of the Internet in Hong Kong: A Chain Process Model. *Journal of Computer-Mediated Communication, 7*(2).

Zhu, K., Kraemer, K. L., & Xu, S. (2006). The Process of Innovation Assimilation by Firms in Different Countries: A Technology Diffusion Perspective on E-Business. *Management Science, 52*(10), 1557-1576.

Zigurs, I., & Buckland, B. K. (1998). A Theory of Task/Technology Fit and Group Support Systems Effectiveness. *MIS Quarterly, 22*(3), 313-334.

Zigurs, I., Buckland, B. K., Connolly, J. R., & Wilson, E. V. (1999). A Test of Task-Technology Fit Theory for Group Support Systems. *The DATA BASE for Advances in Information Systems, 30*(3), 34-50.