



Provided by the author(s) and University of Galway in accordance with publisher policies. Please cite the published version when available.

Title	The Readiness of High-Technology Manufacturing Companies to Adopt and Use Radio Frequency Identification (RFID): A Case Study of the Medical Device Sector in Ireland
Author(s)	Mc Guinness, Kevin
Publication Date	2008
Item record	http://hdl.handle.net/10379/358

Downloaded 2024-05-13T06:37:49Z

Some rights reserved. For more information, please see the item record link above.



**The Readiness of High-Technology Manufacturing Companies to Adopt
and Use Radio Frequency Identification (RFID): A Case Study of the
Medical Device Sector in Ireland**

by
Kevin McGuinness

**A Research Dissertation submitted in partial fulfilment for the Degree of
Masters of Science in Technology Management
of the
National University of Ireland Galway**

Faculty of Commerce, Department of Management,
National University of Ireland Galway

Research Supervisor: Dr. Majella Giblin

Date: August 2008

Final Project/Thesis Submission
MSc Technology Management
National University of Ireland, Galway

Student Name: Kevin McGuinness

Telephone: +353.(0)87.6675947

E-mail: kevin_mcguinness@eircom.net

Date of Submission: 29/08/2008

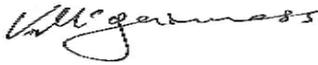
Title of Submission: The Readiness of High-Technology Manufacturing
Companies to Adopt and Use Radio Frequency
Identification (RFID): A Case Study of the Medical
Device Sector in Ireland

Supervisor Name: Dr. Majella Giblin

Certification of Authorship:

I hereby certify that I am the author of this document and that any assistance I received in its preparation is fully acknowledged and disclosed in the document. I have also cited all sources from which I obtained data, ideas or words that are copied directly or paraphrased in the document. Sources are properly credited according to accepted standards for professional publications. I also certify that this paper was prepared by me for the purpose of partial fulfilment of requirements for the Degree Programme.

Signed:



Date: 29/08/2008

Acknowledgements

The decision to undertake this Masters programme was difficult enough in its own right but the completion of it, and particularly this Thesis, would not have been possible were it not for the support and assistance of several key individuals.

To start, I would like to thank my fellow classmates who, through the sharing of their own personal experiences from their various fields and professions, provided many interesting insights and debates on various aspects of innovation in today's workplace.

In particular I would like to thank Ann and Lubos for their company and friendship during the many hours spent driving along the highways and by-ways of Ireland. Your company and conversation over the past two years made the journey to the many group workshops and tutorials a pleasure during this time.

I would also like to thank my research supervisor, Dr. Majella Giblin, National University of Ireland Galway, for all her assistance and guidance during the course of this Thesis and for teaching me the value of a good time plan in any project.

Above all else, I would like to thank my family for their patience, understanding and help throughout the past two years. To my two lovely children, Amy and Aaron, I apologise most sincerely for not being there as much as I ought have been over this time and can only promise to make it up to you again in the near future.

Finally, the most heartfelt thank you of all goes to my beautiful wife, Mary, who carried the burden of my absence during this time and never once complained, despite having every right to do so. Thank you for being there to remind me why it was we took on this particular challenge in the first place.

Table of contents	Page
Certificate of authorship	ii
Acknowledgements	iii
List of tables	vii
List of figures	viii
Abstract	ix
1. Chapter One: Introduction	1
1.1 Background to the research	1
1.2 Research questions	2
1.3 Significance of the research	2
1.4 Outline of the thesis	3
2. Chapter Two: Literature review	5
2.1 Introduction	5
2.2 RFID technology	5
2.2.1 RFID tags	6
2.2.1.1 Passive tags	6
2.2.1.2 Active tags	7
2.2.2 RFID readers	8
2.2.3 RFID applications	9
2.2.4 Benefits of RFID	9
2.3 Disruptive innovations and RFID adoption	10
2.4 Current academic interest in RFID	11
2.5 Barriers and challenges to RFID adoption	14
2.6 Limitations of the research on RFID adoption	17
2.7 Conclusion	17
3. Chapter Three: Research methodology	19
3.1. Introduction	19
3.2. The research questions and the case study approach	19
3.3. Selection of the sector	20
3.4. Selection of the participating organisations	21
3.5. Data collection methods used	22
3.6. Questionnaire and interview design	22
3.7. Conclusion	24

4. Chapter Four: Findings	25
4.1. Introduction	25
4.2. Product mix of organisations	25
4.3. Current level of RFID adoption	25
4.4. Technological, organisational and environmental context	26
4.4.1. Technological context	26
4.4.1.1. Relative advantage	26
4.4.1.2. Compatability	27
4.4.1.3. Complexity	28
4.4.1.4. Cost	28
4.4.2. Organisational context	29
4.4.2.1. Top management support	29
4.4.2.2. IT expertise	30
4.4.2.3. Organisational size	31
4.4.2.4. Organisational readiness	32
4.4.3. Environmental context	33
4.4.3.1. Competitive pressure	33
4.4.3.2. External support	34
4.4.3.3. Change agents	35
5. Chapter Five: Discussion	36
5.1. Introduction	36
5.2. Current level of RFID adoption	36
5.3. Technological context	37
5.4. Organisational context	38
5.5. Environmental context	39
5.6. Research questions	40
5.7. Conclusion	42
6. Chapter Six: Conclusion	43
6.1. The main findings	43
6.1.1. Technological context	43
6.1.2. Organisational context	44
6.1.3. Environmental context	44
6.2. Contribution to academic research	44
6.3. Overall Conclusion	45

References	46
Appendix 1	50
Appendix 2	56

List of Tables	Page
Table 2.1 Comparison of barcodes and RFID	9
Table 2.2 Classification of reviewed literature	12
Table 2.3 RFID adoption challenges	15
Table 3.1 Overview of participating organisations	21

List of figures	Page
Figure 2.1 Components of a RFID system	6
Figure 2.2 Passive RFID tag	7
Figure 2.3 Active RFID tags	8
Figure 2.4 Industrial RFID readers	8
Figure 2.5 Distribution of articles by year	13

Abstract:

Radio Frequency Identification (RFID) has been around for many years now and the perceived advantages the technology offers over other auto-identification technologies has resulted in it being termed a disruptive technology. Yet, despite these apparent advantages, the predicted widespread adoption of RFID technology across different industry sectors has been slow in materialising. While Retail and Supply Chain Management applications have grown in numbers in recent years, other industries appear to be lagging some way behind.

This study examined the readiness of the high-technology manufacturing industry to adopt and use RFID technology in its products and processes through a case study analysis of the Irish medical devices sector, one of the most significant and technically advanced manufacturing sectors in Ireland.

The study concluded that, at the time of completion of the study in August 2008, the industry was not yet ready to adopt RFID technology, though there was a desire by many organisations to work towards that goal. However, in order for this to happen a number of significant barriers must be overcome before wide scale adoption of the technology is possible.

These barriers can be classified under the three main contexts of technological, organisational and environmental issues and includes factors such as cost and management support. Two of the key factors identified in this study are the impact with which the organisations size can have on adoption and the impact that external change agents such as the FDA will potentially bring to bare on adoption.

1. Chapter One: Introduction

1.1 Background to the research:

Radio Frequency Identification (RFID) is a type of auto-identification technology that uses radio waves to identify unique items (Brady et al, 2006) which is gaining increasing popularity in a number of applications where there is a need to collect multiple pieces of data on items for tracking and counting purposes, such as from security and access control through to transportation and logistics applications (Brown and Bakhru, 2006, p.4).

RFID technology has been described as a disruptive technology (Vail and Agarwal, 2007) which has the potential to revolutionise the way in which products are identified and tracked throughout the supply chain because of the significant advantages it is believed RFID holds over traditional auto-identification technologies such as barcodes. For example, the ability to read stored information without the need for a line of sight, larger data storage capacity and enhanced security features (Kumar et al., 2007) are just some of the reasons why it is felt that RFID could potentially replace barcodes entirely at some point in the future.

Despite these apparent advantages, RFID technology itself has been characterised by a slow rate of adoption (Brown and Bakhru, 2006) within many organisations and industry sectors. While this has improved somewhat in recent years, particularly in the retail sector, where mandates from the likes of Wal-Mart and the US Department of Defence have demanded their largest suppliers adopted RFID technology throughout their supply chain and logistics operations, the overall adoption of RFID remains slow. The aim of this study is to determine the level of RFID adoption within the high-technology manufacturing sector, while also determining what factors are contributing to this low level of adoption and examining how these barriers may be overcome.

1.2 Research questions:

Therefore, this study shall seek to address one primary research question:

PQ.1: “How prepared are high technology manufacturing companies for the adoption and use of RFID technology solutions?”

In addressing this primary research question the study shall also seek to answer the following related secondary research questions:

SQ.1: “What, if any, are the benefits of RFID adoption and use by companies in the high technology manufacturing sector?”

SQ.2: “What, if any, are the barriers and challenges inhibiting the adoption and use of RFID technology in the high technology manufacturing sector?”

SQ.3: “How, if at all, can these barriers be overcome?”

1.3 Significance of the research:

There was been a widespread increase in the level of academic interest in and around RFID technology over recent years. Yet, many of the studies on RFID to date have focussed on the adoption and use of RFID technology within the Retail sector and the Supply Chain Management (SCM) business. A number of studies have highlighted the gap that exists between the benefits that RFID technology has to offer in the first instance and the reality of the challenges that exist in actually adopting and implementing the technology across different geographical regions and industry sectors (Brady et al, 2006; Brown and Bakhru, 2006; Brown and Russell, 2007).

This study proposes to address this gap by examining the readiness of high-technology manufacturing organisations to adopt RFID technology in their products and processes. In order to achieve this, the study shall focus on a case study of the Irish medical devices sector. The study shall also identify what barriers, if any, exist within the overall sector that may currently be preventing its members from realising the benefits associated with RFID

technology and thus preventing them from adopting the technology within their own organisations.

1.4 Outline of the thesis:

The study is broken in to a total of six definable chapters. This chapter, chapter one, outlines the overall structure of the thesis beginning with an outline of the background to the study and discusses the significance of the study to the area of RFID research.

Chapter two reviews the current literature with regard to RFID technology. It begins with a brief description of the technology behind RFID itself and discusses the various components that make up an RFID system, principally RFID readers and tags. It also highlights some of the current applications where RFID technology is used and discusses some of the benefits of RFID by drawing comparison to other auto-identification technologies such as barcode. The chapter continues with a definition of disruptive technologies and examines the current academic interest in RFID technology, placing a particular emphasis on the barriers and challenges to RFID technology adoption that have been identified by a number of different studies thus far. Finally, the chapter concludes with a description of the limitations of the research within the current literature for the high technology manufacturing sector.

Chapter three discusses the research methodology employed in the study, beginning with a statement of the research questions to be addressed in the study and outlining the thought process and reasoning behind opting for a case study approach to answer these research questions. The chapter then continues with an explanation of why the medical device sector was chosen as the focus of the study in the first instance before providing an overview of the participating organisations in the study and giving details of the type and size of organisations involved. The chapter then concludes with a description of the various data collection methods employed in the study and outlines the thought process behind the structure and design of the questionnaire and interview questions contained within the study.

Chapter four presents the findings from the questionnaires and interviews conducted with the four participating organisations in the study. It begins with a look at the product mix of each of these organisations and describes the current level of adoption of RFID within those organisations. The chapter continues to discuss the specific findings related to each of the three contexts of technological context, organisational context and environmental context and concludes with a summary of the key findings arising out of the study.

Chapter five goes on to discuss the findings of the study in more detail and to analyse and discuss the implications of these findings. It begins with a look at the level of adoption of the organisations and discusses what this might mean for the high technology manufacturing industry as a whole. Finally, it concludes with a detailed discussion of each of the three contexts, technological context, organisational context and environmental contexts.

Finally, the last chapter, chapter six, summarises the entire study beginning with a description of the study's main findings and how the study contributes to the academic research in the area of RFID technology adoption. The chapter then goes on to describe the limitations of the research and the implications for future research, before concluding with an overall summary of the entire study.

2. Chapter Two: Literature Review

2.1 Introduction

Radio Frequency Identification (RFID) is the generic term used to describe a type of auto-identification technology that uses radio waves to identify unique items (Brady et al, 2006). Essentially, RFID can be used in any application where there is a need to collect multiple pieces of data on items for tracking and counting purposes, such as from security and access control through to transportation and logistics applications (Brown and Bakhru, 2006, p.4).

It is believed that RFID has the potential to offer such significant advantages over traditional auto-identification technologies, like barcodes, that this technology could eventually become the de-facto technology in the near future, leading some to describe RFID as a “disruptive technology” which has the potential to revolutionise the way in which people and products interact (Vail and Agarwal, 2007).

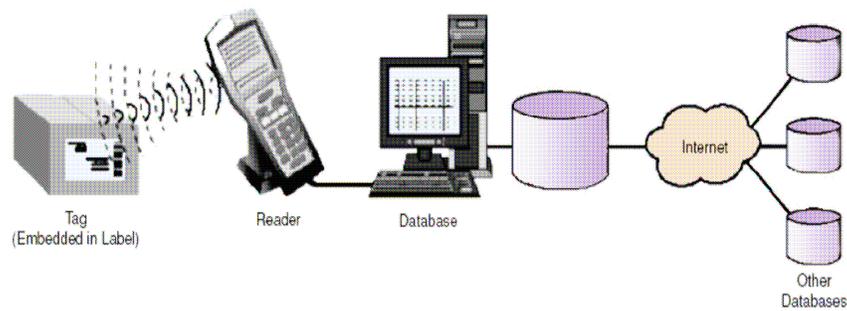
This chapter discusses some of the technical aspects of RFID technology and establishes whether RFID can correctly be termed a disruptive technology. The current literature is reviewed with regard to the academic interest in RFID technology, placing an emphasis on the perceived barriers to its wide scale adoption, and finally identifies where gaps exist in the current literature.

2.2 RFID technology

Radio Frequency Identification (RFID) is the generic name for a type of auto-identification technology that uses radio waves to identify unique items (Brady et al, 2007, p.7). Typical RFID systems are made up of two major components: RFID tags and RFID readers.

Figure 2.1 shows how the components of a RFID system work. A RFID reader is used to read the encoded information on the RFID tag and this information can then be placed in a database, or compared with information

in an existing database, for use in tracking, identifying, studying, or other purposes (Vail and Agarwal, 2007).



**Figure 2.1 – Components of a RFID system
(Vail and Agarwal, 2007, p.27)**

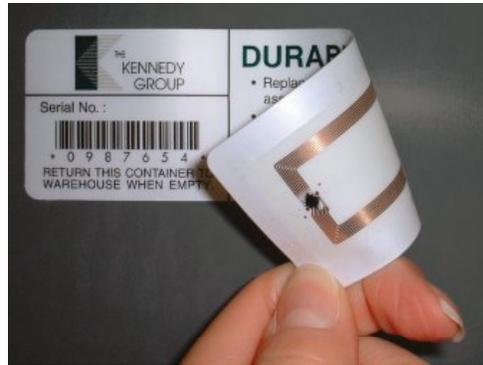
2.2.1 RFID tags

An RFID tag, or transponder contains a small microchip that is attached to an antenna. The microchip is capable of storing encoded information such as a unique identification number which can be retrieved when activated by a suitable RFID reader. RFID tags come in many different forms and sizes and can be either Active or Passive (SystemLabel.com).

2.2.1.1 Passive tags

Passive tags, as their name implies, have no internal power, or if they do they do not use it in the transmitting of the signal. Passive tags are energised via the incoming Radio Frequency (RF) signal from the reader, which generates a small current in the antenna. This current activates the silicon chip in the circuit, effectively waking it up and thus enabling the RFID tag to send out a response to the reader. The aerial or antenna of a passive tag is designed to both pick up and transmit an RF signal (SystemLabel.com).

Since they do not require their own power source, passive tags are typically smaller than active tags and can come in a variety of different forms, such as self adhesive labels (see Figure 2.2), laminated paper tickets, laminated plastic cards or enclosed in specialist housings for application on difficult surfaces such as metal.



**Figure 2.2 – Passive RFID tag
(Kennedy Group, 2008)**

Passive tags can have read distances from 2mm (ISO 14443) to a few meters (ISO 18000-6) depending on the particular Radio Frequency used and the design of the antenna. Passive tags may also contain batteries, however these batteries are not for transmitting data but rather for retaining the memory of the tag. As passive tags do not generally have an internal source of power they are cheaper than Active tags (SystemLabel.com).

2.2.1.2 Active tags

Active RFID tags have their own internal power source and continually transmit a signal, or beacon, usually at a set time interval so as to optimise power. They generally have bigger memories than passive tags and the read ranges achievable are typically much larger also, with up to 100m ranges possible in many cases. Active tags are typically found in enclosed housings and come in a range of different sizes and designs to suit many different applications (see Figure 2.3). While the lifetime of each tag is dependent on the time interval of the signal, it is possible to achieve a battery life of between 5 and 10 years (SystemLabel.com).



Figure 2.3 – Active RFID tags

2.2.2 RFID readers

RFID readers, which are often called interrogators or scanners, send and receive Radio Frequency (RF) signals that transmit data to and from the tag via antennas and may have multiple antennas for the transferring and receiving of data (Paxar). RFID readers are usually in the ‘on state’ waiting for a response from any tag that comes within the vicinity of the read zone. However, there are situations, for example with hand held readers, where they are activated via a trigger so as to conserve power. RFID readers can come in many shapes and sizes from small hand held Personal Digital Assistant (PDA) type readers to more industrial fixed readers (see Figure 2.4) such as those typically found in warehousing loading bays (SystemLabel.com).



Figure 2.4 – Industrial RFID reader

2.2.3 RFID applications

RFID technology is used in many applications from item and asset tracking through to security and contactless payment applications (Brown and Bakhr, 2006, p.4). Essentially, RFID can be used in any application where there is a need to collect multiple pieces of data on items for tracking and counting purposes and where other auto-ID technologies such as barcodes are not suitable.

In any RFID application one of the most important considerations will be what data is stored and retrieved, as well as how this data will then be used by an organisation in order to gain competitive advantage. To a large extent this will be determined by whether the application is a closed loop system, in which the RFID readers and tags are all part of a single RFID system, or whether it is part of an open-loop system, which requires it to share information with other applications or systems, usually at a different location entirely.

2.2.4 Benefits of RFID

When trying to outline the benefits of RFID, comparison is usually made with current barcode technology. While barcode and RFID systems both involve tags that are scanned to extract product information from the tagged item, there are distinct differences between the two (Table 2.1). Whereas barcodes use laser light reflections and require direct contact with a scanning device, RFID uses radio frequency transmissions and therefore does not require any line of sight between the reader and the tags (Kumar et al., 2007).

<i>System</i>	<i>Barcode</i>	<i>RFID</i>
Data transmission	Optical	Electromagnetic
Typical data volume	1-100 Bytes	128-8K Bytes
Data modification	Not possible	Possible
Position of data carrier	Visual contact	Non line of sight possible
Security	Little	High
Environmental	Dirt	Little

**Table 2.1 – Comparison of barcodes and RFID
(Accenture 2001, summarised in Kumar et al., 2007, p.57)**

In addition, RFID is capable of storing larger amounts of data, which can be modified as required, and offers enhanced security features when compared to barcodes. These significant benefits over barcode have led some to describe RFID as a “disruptive technology” that will eventually replace barcode technologies entirely in the not too distant future (Vail and Agarwal, 2007, p.25).

2.3 Disruptive innovations and RFID adoption

Vail and Agarwal (2007) define a disruptive innovation as “a new advance that eventually evolves and displaces previous methods, processes, or technologies even though it might not be quite as good as current technology to begin with” (Vail and Agarwal, 2007, p.27). They argue that in the early years of such disruptive technologies it has not been uncommon for them to have “had large negative impacts that were eventually mitigated through voluntary standards, government regulation and customer selectivity” (Vail and Agarwal, 2007, p.27) and give the example of how digital cameras, despite having inferior features such as resolution when first introduced, improved over time to eventually take over the camera market and displace traditional camera technology. (Vail and Agarwal, 2007, p.27). By studying case histories of previous disruptive innovations, they believe it is possible to anticipate problems with emerging disruptive innovations, thus allowing one to address these problems at an early stage. (Vail and Agarwal, 2007, p.25).

Vail and Agarwal argue that RFID is one such disruptive technology that, despite a number of current problems believed to be delaying its widespread adoption, will eventually replace barcode technologies entirely in the not too distant future (Vail and Agarwal, 2007, p.25). Others are less certain that RFID will completely replace the need for barcodes, believing instead that the two technologies are complementary to each other and will therefore co-exist for some time to come (Wu et al., 2006). Others still are more dismissive of the technology itself and argue that much of the earlier literature on RFID amounted to no more than hype by RFID vendors and those with vested interests (Jones et al, 2005, summarised in Brown and

Russell, 2007, p.251) and point to the fact that vendors have been complaining business is not growing as fast as expected (Wu et al., 2006).

2.4 Current academic interest in RFID

Yet, while it is unclear as to what extent RFID will replace barcode technology (Sheffi, 2004), there is no denying that RFID “has become a new and exciting area of technological development, and is receiving increasing amounts of attention” (Ngai et al, 2008, p.511) as scholars investigate how this technology will impact on society and business in the future. Part of the reason for this they contend is due to the relative novelty and exploding growth of RFID, which “has led to the emergence of a new academic research area that builds on existing research in a host of disciplines” (Ngai et al, 2008, p.511).

In their literature search based on the descriptors “RFID” and “radio frequency identification”, Ngai et al (2008) provide a comprehensive review of 85 academic journal papers that were published between 1995 and 2005, which they divide in to four main categories, summarised in Table 2.2.

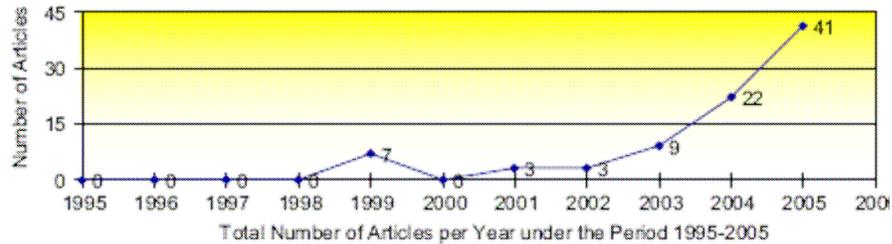
The first of these, RFID technology, focused on articles directly related to the components of an RFID system and was further subdivided into the categories of tags and antennae, readers and communication infrastructure. Next, RFID applications focussed on existing application areas where RFID technology is currently employed, identifying fourteen different industry areas in total. The third category, policy and security issues, focussed on privacy and security in relation to potential misuse and protection of confidential data as well as issues related to the creation of global standards. Finally, the last category, other issues, included publications covering all other aspects of RFID “such as a general introduction and review or the foundations of the concept of RFID” (Ngai et al, 2008, p.513).

1. RFID Technology
<p>Tags and antennae: Takaragi et al. (2001), Frisk et al. (2002), Biebl (2003), Keskilammi et al. (2003), Cabria et al. (2004), Chen and Hsu (2004), Heikkinen and Kivikoski (2004), Hirvonen et al. (2004), Keskilammi and Kivikoski (2004), Rasul (2004), Redinger et al. (2004), Tikhov and Won (2004), Cho et al. (2005), Curty et al. (2005), De Vita and Lannaccone (2005), Kwon and Lee (2005), Nikitin et al. (2005), O et al. (2005), Philipose et al. (2005), Rao et al. (2005), Ritamaki et al. (2005), Smith et al. (2005), Subramanian et al. (2005), Ukkonen et al. (2005), Usami and Ohki (2003)</p> <p>Readers: Repo et al. (2005)</p> <p>Communications infrastructure: Chlamtac et al. (1999), Deville et al. (2002), Ni et al. (2004), Gilbert et al. (2005), Yen et al. (2005)</p>
2. RFID Applications
<p>Animal detection: Artmann (1999), Wismans (1999), Streit et al. (2003)</p> <p>Aviation: Wyld et al. (2005)</p> <p>Building management: Sommerville and Craig (2005)</p> <p>Construction: Jaseiskis and Ei-Misalami (2003), Yagi et al. (2005)</p> <p>Enterprise feedback control: Kohn et al. (2005)</p> <p>Fabric and clothing: Hum (2001)</p> <p>Food: Hall and Hampl (2004), Vorst et al. (2004), Jones et al. (2005a)</p> <p>Health: Venkatesan and Grauer (2004)</p> <p>Library services: Hicks (1999), Kern (2004), Coyle (2005), Fabbi et al. (2005)</p> <p>Logistics and SCM: Jansen and Krabs (1999), Angeles (2005), Twist (2005)</p> <p>Mining: Ruff and Hession-Kunz (2001)</p> <p>Museums: His and Fait (2005)</p> <p>Retailing: Kärkkäinen (2003), Jones et al. (2004a), Eckfeldt (2005), Jones et al. (2005b), Prater et al. (2005)</p> <p>Waste management: Wäger et al. (2005)</p>
3. Policy and Security Issues
<p>Privacy: Garfinkel et al. (2005), Günther and Spiekermann (2005), Kelly and Erickson (2005), Ohkubo et al. (2005), Stajano (2005)</p> <p>Security: Kang and Gandhi (2003), Knospe and Pohl (2004), Phillips et al. (2005), Shih et al. (2005)</p> <p>Standardization: Jansen and Eradus (1999), Kampers et al. (1999)</p>
4. Others
<p>General usage: Stanford (2003), Lapide (2004), Want (2004), Borriello (2005), Weinstein (2005)</p> <p>General introduction/review: Ferguson (2002), Rappold (2003), Jones et al. (2004b), Juban and Wyld (2004), McGinity (2004), Sangani (2004), Sheffi (2004), Goth (2005), Lai et al. (2005), Smith (2005)</p>

**Table 2.2 – Classification of Reviewed Literature
(Adapted from Ngai et al, 2008, p.517)**

While stressing that their research is not exhaustive, the study does highlight that in the ten-year period between 1995 and 2005 there was a marked increase in the number of papers published in the latter half of this period, compared to the first half of the same period (Figure 2.5). With 9 papers published in 2003, followed by 22 in 2004 and 41 in 2005 it is

understandable to see how the authors could declare that “academic research into radio frequency identification (RFID) has proliferated significantly over last few years, to the point where journals are producing special issues on the topic”(Ngai et al, 2008, p.510).



**Figure 2.5 – Distribution of articles by year
(Ngai et al, 2008, p.510)**

Ngai et al. (2008) also highlight that, of the total number of articles within the applications category, most were related to the areas of Retail, Logistics and Supply Chain Management. Indeed this trend has not gone unnoticed by others with many scholars highlighting the fact that much of the recent research in RFID has been largely focussed on the impact the technology may have in the areas of Supply Chain Management and in the Retail sector in particular (Brown and Russell, 2007; Brady et al, 2006; Brown and Bakhru, 2006; Angeles, 2005). Ngai et al. (2008) suggest that the reason for this may lie in the fact that RFID “has emerged as part of a new form of inter-organisational system that aims to improve the efficiency of the processes in the supply chain” (Ngai et al, 2008, p.510) and state that this may have been brought about in part by the mandatory RFID tagging decrees of Wal-Mart and other large retailers.

Brady et al (2006) point to the fact that, while there has been much written about the benefits of RFID for Supply Chain Management, there is a “significant dearth of literature reporting the challenges and opportunities of the technology” and that RFID remains overlooked and under exploited as a result (Brady et al, 2006, p.2). Certainly it is generally accepted that, despite being called a revolutionising technology and offering the advantages that such a new technology brings, RFID technology itself has been characterised

by a slow rate of adoption and that this slow rate of adoption of RFID technology “can best be explained with reference to the literature on technology adoption” (Brown and Bakhru, 2006, p.3)

2.5 Barriers and challenges to RFID adoption

Indeed, there have been many studies carried out over the years that have examined the ability of companies to readily adopt new disruptive innovations or technologies as they emerge as well as examining and detailing the challenges that such companies typically encounter in order to adopt these new technologies. For example, the adoption of the Internet across almost all sections of society and business has been a particularly well-studied area of technology adoption in more recent times (Del Aguila-Obra and Padilla-Melendez, 2006; Durkin et. al, 2008). Such studies have shown that many of these new technologies go through a similar cycle, or stages, during adoption and some point to theoretical frameworks such as Rogers (1983) innovation adoption theory, which they argue are appropriate “to explain the innovation adoption process in organisations and to describe what factors influence it, as well as to identify the phases within this process” (Del Aguila-Obra and Padilla-Melendez, 2006, p.95).

While Brown and Bakhru (2006) agree that the technology adoption passes through a number of different stages, they also argue that the successful implementation of a technology can only be signalled, “when it has achieved widespread deployment and complete exploitation for business value” (Brown and Bakhru, 2006, p.9). Furthermore, they continue that, “Although the decision to purchase is an important turning point, adoption can not be said to have taken place until implementation has been achieved at least to the extent that some employees make use of the applications on some level” (Brown and Bakhru, 2006, p.9)

Therefore, understanding the factors that impact on technology adoption is important since, “despite the numerous opportunities for RFID, it seems that there is still a long way to go before its extensive global application is achieved” (Ngai et al, 2008 p.517) and “there are many challenges that need

to be overcome and a host of problems to be solved to expedite the widespread implementation of RFID” (Ngai et al, 2008 p.517).

Types of challenges	Challenges issues	Description
Technology challenges	<ul style="list-style-type: none"> ▪ Material effects on antenna power pattern ▪ Tag antenna orientation affects radio wave reception ▪ Collision caused by simultaneous radio transmission 	The antenna plays an important role in communication between tag and reader. Radio waves can be reflected or refracted by different materials, which in turn can affect the strength of the signal.
Standard challenges	<ul style="list-style-type: none"> ▪ Lack of unified RFID standard ▪ Lack of consistent UHF spectrum allocation for RFID 	The lack of a complete and international unified standard is causing many enterprises to hesitate in adopting RFID systems
Patent challenges		Vendors are concerned about high patent royalty payment, which presents an obstacle to RFID adoption.
Cost challenges	<ul style="list-style-type: none"> ▪ Manufacturing costs ▪ Customization costs 	Costs could refer to that of the microchip, the cost of the inlay (substrate and antenna), cost of assembly and licensing costs.
Infrastructure challenges		<p>The implementation of systems will incur considerable system design, customization and configuration costs.</p> <p>The adoption of UHF RFID systems for supply chain management will benefit many companies and process flows. However, because so many infrastructures of enterprises are required to interact with each other, big infrastructure challenges exist.</p>
ROI challenges		There is shortage of comprehensive information to evaluate RFID installation costs and Return on Investment for enterprises.
Barcode to RFID migration challenges		Barcode systems are currently adopted by many enterprises. RFID is only developing, so enterprises may need to operate dual systems, doubling the cost of maintenance.

**Table 2.3 – RFID adoption challenges
(Wu et al., 2006; Adapted from Chao et al., 2007, p.276)**

Wu et al. (2006) identify seven key challenges and obstacles that they believe are currently impeding the widespread adoption of RFID technology (see Table 2.3). These challenges include technological issues with the technology itself, issues surrounding global unified standards, concerns over patent issues and royalty payments, issues surrounding the cost of manufacturing and customisation, challenges due to the infrastructure changes that will be required, difficulties associated with evaluating the

Return on Investment (ROI) for new RFID systems and the inevitable challenges for companies migrating from barcode to RFID systems.

Brown and Russell (2007) further echo many of these challenges and also express the view that much of what needs to be studied with regard to the adoption of RFID technology can find its roots in the large number of studies already completed on technology adoption in the field of Information Systems (IS). However, they point out that most of these studies have tended to place the individual as their unit of analysis. Such theories they argue are not appropriate for innovations adopted by organisations, since key organisational and environmental factors are not taken into account and suggest that a better framework for studying organisational adoption is one in which factors affecting organisational adoption are grouped into three different contexts, namely technological, organisational and environmental.

In the first of these, technological context refers to variables such as relative advantage of the technology, complexity of implementing and using the technology, compatibility of the technology with current technologies and the costs associated with the technology are some of the factors most regularly cited (Schmitt et al, 2007; Brown and Russell, 2007).

With regard to the organisational context, characteristics can include the level with which top management actively support and drive the implementation and adoption of the technology, the size and structure of the organisation, the readiness of the organisation to modify its business processes and the level of internal expertise within the organisation to implement and support the technology (Schmitt et al, 2007; Brown and Russell, 2007).

Lastly, the environmental context refers to characteristics external to the organisation and could include factors such as pressures arising out of the activities of competitors, the availability and quality of support from vendors and manufacturers and the influence of change agents such as regulatory bodies within the industry (Schmitt et al, 2007; Brown and Russell, 2007).

This view that the emphasis on adoption of RFID technology should be placed at the organisational level is also supported by other scholars since, “It is argued that adoption decisions are dependent in the first instance on the potential impact of new technologies on the organisation in its entirety” (Brown and Bakhru, 2006, p.3).

2.6 Limitations of the research on RFID adoption

The contention put forward therefore is that “prior studies have not always investigated the three contexts (technological, organisational environmental) comprehensively” (Brown and Russell, 2007, p.251) rather, to date, many of the studies on RFID adoption have tended to focus narrowly on a few key factors such as cost (Hoske, 2004), privacy (Jones et al., 2004), key benefits and challenges (Jones et al., 2005; Li et al., 2006) (as summarised in Brown and Russell, 2007, p. 251).

In addition, while there are many studies on the adoption of RFID technology in the Supply Chain Management and retail sectors, the available literature on the adoption process and impact of RFID within other sectors, such as the high technology manufacturing sector, is noticeably sparse. This is even more noticeable in specialist areas of the high technology manufacturing sector, such as the medical device-manufacturing sector. Those studies that do exist tend to focus more on the use of RFID in the healthcare sector rather than in the manufacturing processes of the devices themselves (Shim, J.P., 2007).

2.7 Conclusion

In summary, the current literature on RFID acknowledges the growing importance of the technology in today’s society and the increased academic interest and studies that have arisen as a result. Many such studies have focussed on the adoption and use of RFID technology in both retail and supply chain management applications and have noted the many challenges and obstacles that the introduction of new technologies often presents. While many of these studies put the individual at the centre of the study it is argued

by some that a far better approach is to place the organisation at the centre of the study.

This study therefore aims to fill the gap identified by Brown and Russell (2007) with regard to the adoption of RFID in other countries and other sectors, by adapting their framework to the carry out a case study analysis of the high technology medical device manufacturing sector in Ireland. In doing so this study shall test the eleven propositions put forward by Brown and Russell (2007) in their study and determine if the same factors limiting adoption in the Retail sector are also applicable to the high-technology manufacturing sector, by examining the three key contexts of technological, organisational and environmental factors identified earlier.

3. Chapter Three: Research methodology

3.1 Introduction

This chapter explains the research methodology employed in the study, beginning with a statement of the primary and secondary research questions to be addressed in the study and outlining the thought process and reasoning behind opting for a case study approach to answer these research questions. The chapter then continues with an explanation of why the medical device sector was chosen as the focus of the study in the first instance before providing an overview of the participating organisations in the study and giving details of the type and size of organisations involved. The chapter then concludes with a description of the various data collection methods employed in the study and outlines the thought process behind the structure and design of the questionnaire and interview questions contained within the study.

3.2 The research questions and the case study approach

This study proposes to examine the readiness of high-technology manufacturing organisations to adopt RFID technology in their products and processes by focusing on a case study of the Irish medical devices sector. The study shall also identify what barriers, if any, exist within the overall sector that may currently be preventing its members from realising the benefits associated with RFID technology.

The study shall seek to address one primary research question:

***PQ.1:** “How prepared are high technology manufacturing companies for the adoption and use of RFID technology solutions?”*

In addressing this primary research question the study shall also answer the following related secondary research questions:

***SQ.1:** “What, if any, are the benefits of RFID adoption and use by companies in the high technology manufacturing sector?”*

SQ.2: “What, if any, are the barriers and challenges inhibiting the adoption and use of RFID technology in the high technology manufacturing sector?”

SQ.3: “How, if at all, can these barriers be overcome?”

Since a case study strategy has a considerable ability to generate answers to ‘what?’, ‘why?’ and ‘how?’ questions (Saunders et al., 2007, p.139) it was determined that a multiple case study approach would be the best approach to employ in this study.

3.3 Selection of the sector

In the first instance, so as to avoid the possibility of changes due to country or culture specific characteristics, the study concentrated on organisations located in one country (Del Aguila-Obra and Padilla-Melendez, 2006, p.101), which in this case was Ireland. Next, since the purpose of the study is to examine the adoption of RFID technology in a high-technology manufacturing setting, the Irish medical devices manufacturing sector was chosen as the case to be studied.

The medical devices sector is one of the key manufacturing sectors within the Irish economy, accounting for over €6.2 billion in exports each year and employs 11% of Ireland’s total manufacturing workforce (IMDA, 2008). The IMDA also points out that eleven of the worlds top fourteen medical device companies (ranked by medical device revenues in 2005) are based in Ireland and states that over 80% of these organisations are what they term as “innovation active” (IMDA, 2008).

Therefore, it was determined that of all the individual segments making up the overall manufacturing sector in Ireland, one could reasonably expect that the majority of Irish based medical device companies should therefore be sufficiently advanced technically to first be aware of the existence of RFID technology and, secondly, have an understanding of how this technology could benefit their organisations.

3.4 Selection of the participating organisations

In total, the study focused on four organisations, which varied in size from large and medium-sized foreign-owned companies through to smaller-sized indigenous companies (see Table 3.1). The first of these, Company A, is a large US owned Multinational Corporation with in excess of 1,000 employees in its Ireland operation. Company B is an Irish owned multinational corporation with between 500 and 999 employees in its Ireland based facility. Company C is a medium sized US owned firm with between 101 and 499 employees in its Irish facility. Finally, Company D is a small indigenous Irish company with less than 100 employees.

Company	Type	No. of Employees	Level of RFID adoption	Pilot Planned?	Position of Interviewee
A	Large US multinational	>1,000	Spoke formally	No	R&D Packaging Engineer
B	Large Irish Multinational	500-999	Spoke informally	No	Snr R&D Engineer
C	Medium US multinational	101-499	Spoke informally	No	Snr R&D Engineer
D	Small indigenous Irish company	<100	Spoke informally	No	R&D Manager

Table 3.1 – Overview of participating companies

In all four cases the organisations were located in the West and Northwest regions of Ireland. These geographical locations have a large concentration of the total number of medical device manufacturing companies in Ireland and therefore would be representative of the entire medical device sector. Also, within each organisation the interviewees selected for the case studies were all personnel that held senior Research and Development roles and who would all have been aware of RFID to varying degrees.

3.5 Data collection methods used

The study gathered data using a two-stage process. In the first stage, quantitative data was gathered from each of the representatives of the four participating organisations through the utilisation of structured questions in the form of a questionnaire (see Appendix 1), which was emailed to each of the respondents, completed by them and returned to the interviewer during the last week of July 2008.

This was then followed up in the second stage with a semi-structured interview, conducted with each of the respondents from the four participating organisations over the first two weeks of August 2008. The purpose of the semi-structured interview was to gain further qualitative data and add depth to the study by clarifying the interviewees' position with regard to their organisations level of knowledge of and level of adoption of RFID technology. In three out of the four cases the semi-structured interview was conducted at a face-to-face meeting. The fourth interview was conducted via telephone with the respondent from Company C, due to time and geographical constraints involved in arranging a face-to-face meeting. In all four cases, the interview lasted between thirty and sixty minutes, with a taped recording of each interview being taken and stored with the interviewees consent.

3.6 Questionnaire and interview design

In line with the framework devised by Brown and Russell (2007) the questionnaire was divided in to a number of sections and designed to test the technological, organisational and environmental factors which could affect the adoption of RFID.

The first part of the questionnaire included some demographic questions designed to gather basic information about the respondent, such as job title, as well as information on the organisation such as number of employees, a description of the organisations business nature, an indication of their product mix and a measure of the organisations current involvement with RFID technology.

The second section of the questionnaire (S.2) contained a total of eleven statements, each designed around the eleven propositions proposed by Brown and Russell (2007) and shown to have affected the adoption of RFID in the Retail sector. The statements used a 5-point Likert-style scale in which the respondents were asked to rate each statement by means of whether they ‘Strongly agree’ with the statement at one end of the scale through to ‘Strongly disagree’ with the statement at the other end.

The next section of the questionnaire (S.3) asked the respondents to rate the importance to their organisation of a number of perceived benefits by numbering the most important 1, the next 2 and so on. In order to provide the respondents with the option to add additional benefits that may be of importance to them, but which may not have been included in the provided list, an additional option of ‘other’ was also provided with space for additional comments as required.

Finally, the last section of the questionnaire (S.4) asked the respondents to rate the impact of cost on RFID adoption and implementation by again numbering the most important cost consideration 1, the next 2 and so on. As in the case of S.3, this section also provided the respondents with the option to add additional cost considerations of importance to them, but which may not have been included in the provided list, with the addition of an ‘other’ option at the end of the list.

In addition to the questionnaire, further qualitative data was gathered via a series of semi-structured interviews with each respondent. The purpose of the interviews was to clarify and expand on the answers given in the respondents’ questionnaire and to seek out further issues or barriers that might be unique to the high-technology manufacturing sector. Appendix 2 details a number of questions and prompts used during these interviews to tease out supplementary qualitative data in order to add further depth to the data gathered via the questionnaire.

3.7 Conclusion

In summary, the study proposes to examine the readiness of high-technology manufacturing organisations to adopt RFID technology in their products and processes while also aiming to identify what barriers, if any, exist within the overall sector that may be hindering the adoption of RFID technology within the sector.

To achieve this, the study focussed on a case study of the medical devices sector, one of the key high-technology manufacturing sectors within Ireland and gathered a combination of both quantitative and qualitative information through the use of a questionnaire and semi-structured interviews with four medical device manufacturing organisations of varying size and structure throughout July and August 2008.

In essence, the primary research question that the study sought to answer was “How prepared are high technology manufacturing companies for the adoption and use of RFID technology solutions?”

4. Chapter Four: Findings

4.1 Introduction:

The objective of this study was to assess the readiness of organisations in the high-technology manufacturing sector to adopt Radio Frequency Identification (RFID) technology within their products and processes, by carrying out a case study analysis of a selection of medical device companies based in Ireland.

This chapter discusses the findings from the questionnaires and interviews conducted with the four participating organisations. It begins with a look at the product mix of each of the participating organisations and assesses the current level of adoption of RFID within those organisations. The chapter shall also discuss the specific findings related to the three contexts of technological, organisational and environmental as highlighted earlier and shall conclude with a summary of the key findings arising out of this study.

4.2 Product mix of organisations:

In 3 out of the 4 organisations the interviewees described their product mix as “Low volume, high cost”. The remaining organisation, Company B, described their product mix as “Medium volume, high cost” pointing out “sometimes we ship between 200,000 and 300,000 (units) a week”.

4.3 Current level of RFID adoption:

For this question, all four organisations indicated that they had, at the very least, spoken informally about RFID. In one case however, that of Company A, they had actually gone one step further than the others and had formally investigated RFID technology, although there were no immediate plans to follow this up by launching a RFID pilot within their current site any time soon. It was explained that part of the reason for this lay in some of the technical limitations and process issues encountered during their initial trials. In the words of Company A’s representative, “We’ve experienced in the past that we can’t sterilise some of the tags and also, we use a foil pouch, which the tags can’t be read through”.

4.4 Technological, organisational and environmental contexts:

As discussed in earlier chapters the framework applied in this study to examine the organisational adoption of RFID technology groups the factors influencing adoption into three different contexts, namely technological, organisational and environmental.

4.4.1 Technological context

In the first of the three contexts, the technological context part of the questionnaire focussed on four specific factors - relative advantage of the technology, compatibility of the technology with current technologies, complexity of implementing and using the technology and the costs associated with implementing and maintaining the technology.

4.4.1.1 Relative advantage

With regard to whether or not RFID presented their organisations with the opportunity to gain significant benefits over current identification technologies such as barcode, three out of the four organisations agreed that RFID did offer such potential, with Company D going so far as to indicate they strongly agreed with the statement. Comments such as “I think without a doubt, yes, most people will say that of course the advantages are there” would seem to indicate that the majority of organisations are aware of the potential benefits of RFID.

Indeed, it is clear that some of the organisations interviewed have even considered how RFID would benefit them specifically, with one interviewee stating “You would have control over the identification (of parts) through this system, rather than it being manual, which our system is at the minute”. This ability to increase process efficiencies and reduce labour costs were identified as being significantly important across all four organisations, with one interviewee commenting “Labour is our number one cost right now because we have people manually checking that all the components are in place. If a particular technology can help us make savings here, then we have to seriously look at that”.

However, it is worth noting also that Company A, the only company in the study to have formally investigated RFID, indicated that as of yet they are not so sure of the extent of these benefits stating, “I don’t know what RFID could offer above what we have right now other than, I suppose, there would be reduced man power with RFID. But, beyond that, I don’t know how much it could benefit our organisation”.

4.4.1.2 Compatibility

Opinion as to whether RFID tied in with the strategic intent of each organisation was also somewhat mixed. Company A pointed out that one of its long term goals was to implement a system that allowed it to uniquely identify all of its products, adding that “the intent would be to try and look at RFID”. At the other end of the scale, Company B was explicit in its assertion that RFID does not currently have any place in the organisations strategy. Furthermore it was pointed out that this was only likely to change “if some customer demands it or our strategy changes to that level”.

Somewhere in between these differing opinions lay a more uncertain viewpoint for the other two organisations. Although the quantitative data indicated Company C was in agreement with the statement, the qualitative data indicated that the organisations view was a bit more cautious. “It is more so that the benefits that it could give us would be consistent with our strategic intent” Company C’s representative explained and continued to state that “...whether that would happen through RFID or whether it would happen through traditional barcodes, I don’t know”. In a similar fashion Company D was undecided as to how RFID technology was aligned with the strategic direction of the organisation. While “(the organisation) is always looking towards new technologies to gain a competitive advantage” the interviewee also questioned whether the current state of RFID could be likened to the early years of the Internet, stating, “It would probably be of little or no use to us unless everyone is switched on to it”.

4.4.1.3 Complexity

Yet another aspect of implementing RFID technology that showed mixed opinion was the ease with which each of the interviewees felt they could successfully implement RFID within their respective organisations. Perhaps unsurprisingly, Company A was the only company that believed implementing RFID would not be a big issue for them. The reasoning for this assertion was due in part to the experience they gained to date in formally investigating RFID technology as well as the level of sophistication already incorporated within its current systems. “Our systems are set up to read barcode so taking RFID would just be a step beyond that – adapting the system more so than creating new ones,” their representative explained.

The remaining three interviewees were less confident in the capabilities of their organisations to successfully implement the technology if it were required. One interviewee pointed out that within their organisation, “Lots of people know it exists, lots of people would be aware of the high level of benefits, but I don’t know if anyone understands the complexity of implementing it enough to be able to say whether or not it is an issue for us”. Another was even more emphatic that the complexity was beyond their organisations means, citing the fact that “we are a small organisation with very few resources and struggle to maintain our current IT and barcode systems as it is” and therefore saw little hope of them being able to implement a more complex system such as RFID on their own.

4.4.1.4 Cost

In the first of just three questions where all respondents were in total agreement, the quantitative data showed that all four interviewees were unsure as to the whether or not the cost of implementing RFID is justified by the benefits that one could expect to receive. However, once again the qualitative data revealed that each organisation had slightly different perspectives on how the cost would impact them. For the larger organisations, the cost of the initial installation was less of an issue, with one interviewee explaining that “the infrastructural costs are a once off, and if that can be justified then that is fine”. The smaller organisations however had

a different opinion with one stating “the initial set up cost would be the problem” and that “system integration cost (for the organisation) would be a big thing”.

However, one thing that all were in agreement on was that the ongoing costs of consumables such as RFID tags would be a key factor in the implementation of RFID within their respective organisations with one interviewee summing it up thus; “the more pressing concern will be the ongoing costs because if these labels are so expensive it’s not really worthwhile spending money on infrastructure then”. Another who, having already investigated the option of replacing an existing barcode label with an RFID label, found that “it significantly increases the price of our existing label” backed up this view. The uncertainty therefore as to whether the benefits outweigh the costs is best summarised by the comment of one interviewee who reasoned that “it will depend on whether our customers are willing to pay for it”.

4.4.2 Organisational context:

In the second of the three contexts, the questionnaire focussed on four key organisational contexts, which were the level with which top management actively support and drive the implementation and adoption of the technology, the level of internal expertise within the organisation to implement and support the technology, the size and structure of the organisation and the readiness of the organisation to modify its business processes.

4.4.2.1 Top management support

In three out of the four cases studied, it was found that the top management in these organisations were not proactively supporting RFID or leading its implementation within the organisations. In one case the interviewee was quite emphatic of this stating, “No, definitely not. It is not on their radar. I have no doubt they are aware of it and I have no doubt that they are tapping in to our customers to see what their thoughts on it are, but it is not something that they are proactively working on”. Another was less certain,

commenting, “If they are, I definitely don’t know about it. It might be happening at levels that I am not aware of, but I haven’t heard it being mentioned”. That top management could possibly be leading such a drive unknown to others in an organisation may be explained by one interviewees view that “within an organisation like ours, it could be talked about at corporate level and not at a site level at this stage”.

The situation in the remaining organisation was found to be quite different. In this case, top management were found to be very much involved in assessing the technology and deciphering where the organisation could unearth the maximum possible benefits. The qualitative data revealed that in this organisation the senior management team had not only researched the technology but had also invested significant time and resources in attending various conferences and tradeshows and were keeping their pulse on what was happening in the RFID area. One explanation offered by this organisations representative for this was that “they are fairly familiar with the fact that the Food and Drug Administration (FDA) are looking at it as well, so it will be something that is supported. As well as that, maybe they are looking at benefits we don’t see”.

4.4.2.2 IT expertise

Of all the questions asked of the respondents, this question was probably the only one in which the size of the organisation was clearly reflected in the answers. To begin with the largest organisation, Company A, indicated that it could see no problem with integrating and maintaining a RFID system since the organisation would have both a “very strong IT department and a very strong technical background”. On the other hand Company B, the next largest organisation in the study, felt that although resources are often stretched within the organisation sufficient IT expertise would most likely be available internally but could not say for sure.

In contrast, the two smaller organisations studied were under no illusions as to the lack of internal IT expertise each could afford to dedicate to the implementation and maintenance of any future RFID systems. In the case of

Company C this point was made clear from the following statement: “there is an IT person here but it’s mainly from a PC (desktop) support point of view. Networks and servers are dealt with through corporate. So, from a site point of view, I would think that we definitely need more expertise”. In a similar vein, the situation in Company D was even more stark, with their representative pointing out “we don’t have any internal IT support at all”, relying entirely on once weekly site visits as part of a service agreement with a local IT technical support company.

One other item of note to come out of the qualitative data for this question was the recognition by most of the organisations that any implementation of RFID “would probably be through a cross-functional team”. While some acknowledged that this may “be lead by IT”, another felt that it may be more appropriate for functions such as Packaging Engineers to drive any implementation, pointing to the fact that “more often than not it goes on the packaging as opposed to the product or device itself”.

4.4.2.3 Organisational size

Again, as in the previous question, the data gathered from this question would seem to suggest that the size of the organisation itself has a lot to bear on the answer to this particular question. Certainly the two largest organisations both agreed that there were already sufficient resources in place in their respective organisations to experiment with the technology should the decision be made to adopt RFID, prompting one respondent to comment “if this is something that management want to adopt, then they would throw a team at it and make sure it gets done”.

In the case of the two smaller organisations the lack of sufficient resources was clearly more noticeable, although it was felt by one respondent that this should not necessarily be an issue in piloting RFID. Pointing out that “larger sites (within the same organisation) would have more resources” this respondent was of the belief that any decision to implement RFID would probably be taken at a corporate level and therefore could be piloted at the

most suitable site first, before being rolled out across all sites once proven, “as we have done with other technologies in the past”.

4.4.2.4 Organisational readiness

Once again the quantitative data for this question showed a broad agreement among all four organisations with two organisations disagreeing with the statement and the remaining two answering that they were not sure. One of those that were categorical in their disagreement with this statement explained that it was primarily down to the risk factor, stating, “If I think about why we wouldn’t take the plunge on this, it’s the risk that you would invest in this and it would not be a runner”. The same respondent however also refused to rule out the possibility that their organisation may implement RFID at some future date, choosing instead to simply state “not right now” and further adding “again it comes back to whether we were forced into it by our customers”.

On the other hand, one of those that were not sure about this statement explained “The uncertainty there is to do more with adapting the business processes. Ideally we would probably take in something that would fit our organisation. We would go to a vendor or a supplier and say ‘this is our process, this is the way we want it to work, can you supply it that way?’ as opposed to us going to a vendor saying ‘we want RFID, tell us what we need to do to get it in’. Obviously we’ll be flexible enough, but because we are medical devices, we can change very little because of regulation”.

Indeed the issue of regulation was a common theme with each organisation in relation to this statement and, while the organisations themselves may be willing to adapt their processes to aid RFID implementation, it was clear from all respondents that any such changes would be slow to implement and strictly controlled. In the words of one respondent “change isn’t just looked at as something that is good, it’s looked at how will this impact the quality of our product, what are the regulations, what do we have to change to meet those regulations. So, because it’s so highly regulated, change is not just

expected straight away. There are a lot of implications that have to be thought out first”.

4.4.3 Environmental context:

Lastly, the section of the questionnaire focussing on the environmental context included three statements on characteristics external to the organisation, namely pressures arising out of the activities of competitors, the availability and quality of support from vendors and manufacturers and the influence of change agents such as regulatory bodies within the industry.

4.4.3.1 Competitive pressure

For this statement the quantitative data shows that three out of the four organisations studied were in agreement that adoption of RFID would be influenced by what their competition was doing in this regard, with one of the three strongly agreeing. Interestingly though, the qualitative data unearthed slightly different reasoning behind the respondents agreement. In one case the interviewee reasoned that “if our competition starting offering it that would probably be because our customers wanted it, and if our customers want it then we need to be doing it”. On the other hand, a second interviewee was more precise stating that “if it’s something that the competition is doing and using very successfully then it is something that (the organisation) would look at”. While the difference here is subtle, it would seem to suggest that whereas the first organisations reaction would merely be to ensure it doesn’t get left behind, the second organisation would be more cautious and only follow its competitors once they have demonstrated a clear benefit.

Surprisingly, the only organisation to disagree with the statement in the quantitative data, showed a similar sentiment in the qualitative data as that above stating “unless it was showing a competitive advantage we would not be concerned about what our competitors are doing”. It would appear therefore that all organisations are in broad agreement that, while they would be closely monitoring what their competition is doing with regards to RFID,

they would not be inclined to implement such technologies without clearly seeing a benefit for their efforts.

4.4.3.2 External support

In just the second of three statements in which all four organisations were in absolute agreement, the quantitative data for this statement showed that all four organisations were unsure as to level of support and service available from vendors and manufacturers with regard to ongoing support and maintenance of RFID systems. In most of the cases it was found that this was because these organisations simply had no idea of what vendors and support existed in the first instance, having never met with or spoken directly to such vendors. This was typified in the comment of one of the respondents who said, “I don’t have a clue about after sales support or indeed about vendors”.

In another instance it was acknowledged that much of the organisations early research into RFID technology has been conducted via various industry journal articles and browsing through a number of RFID vendor websites. This in itself may present one of the first problems faced by an organisation examining the options for implementing RFID technology with one respondent commenting, “RFID has surfaced several times over the past couple of years and each time the team investigating it has come back with a different slant on it than those that previously looked at it” and, as a result, “one of the biggest problems for us has been figuring out who is actually the right person to be talking to”.

Even in the case of Company A, who have already went through the process of selecting suitable vendors for their early evaluation of the technology, concerns remain as to what would happen if they were to scale up their implementation. In the words of their representative “if we were to implement something like this it would be on a fairly large scale and any of the vendors we have come across might not be able to support such a large scale”.

4.4.3.3 Change agents

Finally, and perhaps most significant of all, is the role in which industry bodies such as the Food and Drug Administration (FDA) and the International Standards Organisation (ISO) are likely to play in influencing all of the organisations to adopt RFID technology, or not. The quantitative data for this statement shows that of these eleven key statements, this was the only one with which all four respondents strongly agreed. Indeed many of the respondents reaffirmed their agreement with positive words and phrases such as “absolutely”, “certainly” and “without doubt”.

What was noticeable too from the accompanying qualitative data was that all of the organisations, regardless of their size, were certainly conscious of the level of authority bearing down on them from these organisations, particularly so in the case of the FDA. Indeed, referring to such organisations, one respondent commented that “They have such power over us, we are so heavily regulated that whatever they say, themselves and the ISO bodies, have a lot of influence over our business”.

Equally, most of the respondents were also mindful of the fact that the FDA also had the power to halt the adoption of RFID in its tracks, with one commenting, “if the FDA came out in the morning and said we do not agree with RFID then that’s it”.

However, most were in agreement that was that this was unlikely to happen and the general feeling was that it was a matter of when, rather than if, the FDA would push the adoption of RFID technology forward, possibly through the issuing of an appropriate mandate. As one interviewee put it, “the FDA are certainly looking at it as a guideline and guidelines tend to become regulations at some time”.

5. Chapter Five: Discussion

5.1 Introduction:

The objective of this study was to assess the readiness of organisations in the high technology manufacturing sector to adopt Radio Frequency Identification (RFID) technology within their products and processes. In doing so, the study applied a framework adapted from Brown and Russell (2007) and gathered a combination of both quantitative and qualitative data to test whether the eleven propositions put forward by them with regard to RFID adoption in the retail sector could equally be applied to the manufacturing sector.

This chapter shall now examine the implications of the study's findings beginning with a discussion on the current level of adoption before discussing each of the three contexts, technological, organisational and environmental, in turn.

5.2 Current level of RFID adoption

To begin with, the study highlighted that the current level of adoption of RFID technology within the medical device sector was low. In fact, if we are to take the assertion of Brown and Bakhru (2006) that "adoption can not be said to have taken place until implementation has been achieved at least to the extent that some employees make use of the applications on some level"(Brown and Bakhru. 2006, p.9) then it must be stated that none of the four organisations participating in this study can be said to have adopted RFID technology since none had yet reached the point where they were receiving any benefits from the technology.

However, that is not to say that these organisations are not considering RFID technology. On the contrary, the study found that all four organisations had spoken either formally or informally about the technology and still had a strong intention to progress this further at some future date. In accordance with the findings of Brown and Russell (2007) therefore, this "positive intention" (Brown and Russell, 2007, p.250) can be explained by considering

the three contexts of technological, organisational and environmental as described earlier.

5.3 Technological context

With regard to the technological context, and in agreement with the findings of Brown and Russell (2007), it is clear from the study that a majority of the organisations can see the potential in RFID technology when compared to current identification technologies such as barcode and would be hopeful to profit from these benefits at some future date. Of the potential benefits presented, increased process efficiencies and reduced labour costs were identified as being of most importance to all of these organisations. Somewhat surprisingly though, a number of the most widely cited benefits of RFID, namely the ability to uniquely identify items and the ability to scan such items without a line of sight (Kumar et al., 2007), did not emerge as being of particular important to these organisations.

However, in disagreement with their findings, the study noted two differences of opinion with regard to the technological context. Firstly, while Brown and Russell (2007) found a general belief that the technology was compatible with the long-term direction of the retail industry, the majority of organisations in this study were unsure as to the long-term strategic role that RFID is likely to play within the medical device industry as a whole.

Secondly, few of the participating organisations in this study were of the opinion that the complexity of implementing a RFID system would not be an issue. Reasons for this difference of opinion may lie in the selected samples of both studies. Whereas in the case of Brown and Russell (2007) the selected sample consisted of only large organisations, this study concentrated on a wider representation of the medical device sector and therefore included organisations of varying degrees of size, from indigenous small to medium enterprises (SME) through to large scale multinational corporations.

5.4 Organisational context:

With regard to the organisational context another difference that emerged between Brown and Russell (2007) and this study centred on the involvement and interest of top management in supporting RFID adoption within their respective organisations. Whereas the findings of Brown and Russell (2007) indicate wide scale support for RFID across the organisations in their sample, the findings of this study differed somewhat. While it was found that the top management in each of the organisations were aware of RFID and the potential benefits it presented, in the majority of cases there was little evidence to suggest they were keen to drive the adoption of RFID forward or to integrate it to any meaningful degree within their organisations strategy. This was certainly the case in the smaller organisations studied, although there does appear to be some evidence to suggest that the larger organisations are more actively involved in assessing the technology and driving its adoption forward, albeit slowly.

Similarly, some disagreement was found to exist between both studies with regard to the level of internal resources, and Information Technology (IT) support in particular, required to implement RFID technology and the degree of ease with which these skills could be transferred from external experts where required. As before, this study found this to be a bigger issue for the smaller organisations interviewed than their larger counterparts and it was felt that this would directly impact on the ability of these organisations to progress the adoption of RFID. To begin with, the ability of these firms to adequately test and experiment the technology in a real-time or pilot application is limited due to this lack of resources. Where the resources are made available to pilot RFID technology, a successful implementation will require further, long-term commitment by the organisation to integrate RFID with the current IT and manufacturing systems all ready in place and even further resources to maintain this system over its lifetime.

5.5 Environmental context:

Finally, from the point of view of the environmental context both studies were found to be in broad agreement. Firstly, as in the case of the retail sector (Brown and Russell, 2007), it would seem that none of the organisations in the medical devices manufacturing sector are currently under any pressure from their competitors to adopt RFID technology. For many it would seem the risks involved in being the first to adopt the technology is too much to contemplate and thus it would seem each organisation is adopting a cautious approach to the technology.

Likewise, the level of knowledge of what external support and after sales service exists from vendors and manufacturers is very limited in most cases. This could be explained by the fact that the majority of the organisations have not, as yet, proceeded beyond informally discussing RFID within their organisations and have therefore had very little dealings with RFID manufacturers and service providers. For those organisations that have progressed to formally discussing RFID technology there is clearly a feeling that the level of external support that exists currently would be inadequate were those organisations to ramp up their use of RFID technology in the near future. It might be suggested therefore that the RFID industry itself could help in this regard through discussing these issues with the manufacturing organisations in an attempt to understand the manufacturing sectors fears in the first instance and to allay or address those fears as required.

Above all else, the overwhelming factor to emerge out of this study is the sense that if RFID adoption is to occur within the medical device manufacturing sector it will be as a result of specific mandates issued by the FDA or ISO. In this regard, all of the organisations are astutely aware of the FDA's current interest in the technology as a possible means of uniquely identifying all medical devices. That such a system of unique identification is now coming to the fore may be due to the high number of human error related deaths and accidents within the healthcare and pharmaceutical industries over recent years (Reiner, 2005) and the litigation costs that invariably arise as a result.

5.6 Research Questions

Therefore, the study sought to address the following primary research question:

PQ.1: “How prepared are high technology medical device manufacturing companies for the adoption and use of RFID technology solutions?”

In short, it would seem that, as of August 2008, the majority of organisations in the high-technology manufacturing sector are not yet prepared for the adoption and use of RFID technology solutions in either their products or processes. This is particularly so for smaller organisations. In order for RFID technology to be adopted, a number of key technological, organisational and environmental issues would need to be addressed, which are best answered with reference to the following related secondary research questions:

SQ.1: “What, if any, are the benefits of RFID adoption and use by companies in the medical device sector?”

Despite the fact that none of the participating organisations in this study have yet implemented RFID or even carried out extensive testing or trial runs in their organisations, it is clear that these organisations do see potential benefits to RFID technology when compared to current auto-identification technologies. In particular, the study highlighted that the organisations in the medical device-manufacturing sector identified increased process efficiencies and reduced labour costs as being of the most importance to them.

SQ.2: “What, if any, are the barriers and challenges inhibiting the adoption and use of RFID technology in the medical device industry?”

In order to first adopt and implement RFID technology however, the organisations in the medical devices sector identified a number of barriers and challenges that must first be overcome. To start with, technical barriers exist with the technology in that RFID tags in some frequency ranges cannot be accurately read when applied to objects with a high metal or water

content. Similarly, products that must undergo a gamma-sterilisation process, such as is the case for many medical device products, can not have an RFID tag applied before the process since the radiation exposure can damage the tags microchip, rendering the tag useless.

Cost issues were also uncovered as being a potential barrier to RFID adoption, with the on-going consumable price of RFID tags in particular being highlighted in the study as of being a key issue.

However, the greatest barrier to RFID adoption within the high-technology medical device-manufacturing sector would seem to be the regulatory bodies within the industry itself. The Food and Drug Administration (FDA) and the International Standards Organisations (ISO) were identified as having such a restrictive hold on the whole industry, that it would be very difficult for an organisation to quickly adopt and use RFID technology within their existing set-up without having to undergo extensive re-qualification for any affected product or process.

SQ.3: “How, if at all, can these barriers be overcome?”

The study identified that one of the quickest and most likely scenarios that would overcome these barriers and lead to wide-scale adoption would be for the FDA and the medical devices sector itself to mandate that all its member implement RFID within their products as a means of uniquely identifying all medical device products. The study has identified that the FDA is currently considering such a mandate in order to improve the traceability of medical device products throughout the supply chain, thereby improving security and reducing the number of potential medical complications due to poor quality or counterfeit products. Such a mandate could have the added impact of increasing the demand for RFID products and services, increasing competition among vendors and thereby reducing the cost of RFID hardware and tags, removing one of the most significant barriers of all.

5.7 Conclusion

While the adoption of RFID technology within the high technology manufacturing sector, as with other sectors, remains slow there is a feeling amongst many of the organisations that it may only be a matter of time before adoption becomes widespread. However, before this happens a number of barriers need to be overcome. These barriers can be explained in the context of technological, organisational and environmental issues.

Of these, it would seem that one of the factors that will have a significant impact on RFID technology adoption would be the size of the organisations looking to adopt in the first instance, with the larger organisations more willing, able and likely to adopt the technology in the short term. Smaller organisations it would seem are more likely to adopt the technology only after being requested to do so by a customer or after witnessing a competitor demonstrate a competitive advantage through their implementation.

However, the study also identifies that external agents, particularly the FDA, may have the most noticeable impact of all on RFID technology adoption within the sector. While the heavy regulation that the FDA currently imposes on the industry may be one barrier that an organisation looking to adopt the technology might currently encounter, it is equally true to say that the possibility of the FDA issuing a mandate to the sector to include RFID in all medical device products could be the spark that accelerates widespread adoption of the technology by all organisations, regardless of their size.

6. Chapter Six: Conclusion

6.1. The main findings

Academic interest in RFID technology has accelerated in recent years, most notably in regards to the application of RFID within the supply chain management and logistics functions within the Retail sector. This level of interest has transferred to other industry sectors with evidence of the adoption of RFID technology in many new application areas in more recent times.

Yet, despite the general acceptance of the superior benefits that RFID technology offers over competing auto-identification technologies the level of adoption of RFID technology within the high technology manufacturing sector remains slow. Nevertheless, there appears to be a feeling amongst many of the organisations within the high technology manufacturing sector that it may only be a matter of time before adoption becomes widespread. In order for this to happen however, a number of barriers need to be overcome. These barriers can be explained in the contexts of technological, organisational and environmental issues.

6.1.1 Technological context

With regard to the technological context the study found that the participating organisations did believe RFID technology offered significant advantages over other competing technologies but, for the most part, did not believe that these benefits were so significant as to justify the considerable costs believed to be involved in the implementation and maintenance of a complete RFID system at this point in time. In addition, the study unearthed a general feeling that the complexity involved in both the installation and maintenance of such a RFID system was both technically and realistically beyond that of all but the largest high-technology manufacturing organisations.

6.1.2 Organisational context

The difference in the size of organisations was also found to be apparent in the factors making up the organisational context. For example, a clear distinction emerged as to the level of resources that the larger organisations could afford to dedicate to any implementation of RFID technology and, in many cases, the feeling was that a sufficient level of internal expertise already existed in these organisations, which would be more than capable of driving such implementations forward successfully. Indeed, within the largest organisation involved in the study, the top management of the organisation was actively supporting the drive towards such implementation. In stark contrast, the opposite was found to be the situation in the smaller organisations, where limited resources and lack of internal expertise was found to be a limiting factor for these organisations to adopt RFID technology.

6.1.3 Environmental context

Finally, with regard to the environmental context, the study found all of the participating organisations, regardless of size, were keeping a watchful eye on their competitors to see what they were up to in relation to RFID adoption. While none of the organisations plan to adopt RFID technology any time soon, all acknowledged that adoption could be accelerated should competitors show a significant competitive advantage developing through their implementation of the technology. Furthermore, and most significant of all, was the importance with which all organisations attached to the influence of external change agents, particularly the FDA. In absolute agreement, all organisations indicated that the FDA will either present the biggest obstacle to RFID adoption in the medical devices sector or, potentially, will act as the biggest enabler of the technology in the sector if, at some future date, it decides to mandate the use of RFID as a means of unique identification in all medical devices.

6.2 Contribution to academic research

The contribution of the study to the academic research into RFID technology adoption is two-fold. Firstly, it fills the gap identified by a number of other

studies in relation to the adoption of RFID in other countries (Brown and Russell, 2007) and other sectors (Brady et al, 2006) by adding new research to the area of RFID technology adoption within the high-technology manufacturing sector, an area that has been acknowledged as lacking in sufficient academic research. Secondly, it further adds to the existing research on the factors influencing the adoption of new technologies and supports the theory that technological adoption in an organisation is best considered with reference to the technological, organisational and environmental contexts for that organisation.

6.3 Overall conclusion

The study has shown that as of August 2008 none of the four participating organisations had yet adopted RFID technology into either their products or processes despite recognising and acknowledging the advantages that RFID presents when compared to competing auto-identification technologies such as barcode. If it is accepted that the medical device sector is representative of the entire high-technology manufacturing industry, then it could be concluded that the high-technology manufacturing sector is not currently ready to adopt RFID technology.

That said however, all of the organisations have spoken about RFID either formally or informally in the past and there appears to be a conscious effort being made by these organisations to constantly keep up to date with the technology with the view to quickly identifying where new developments could mean commercial benefits can be realised from the technology in the near future.

In addition, the possibility of compulsory mandates from external change agents such as regulatory bodies to implement RFID technology as a means to increase security and conformance within the industry is never far from the minds of these organisations who are all too aware that such mandates could change the entire outlook in an instant.

References:

Angeles, R. (2005), "RFID Technologies: Supply-Chain Applications and Implementation Issues", *Information Systems Management*, Winter 2005, Vol. 22, Issue 1, p51-65.

Brady, M., Fellenz, M. and Armstrong, C. (2006), "The Implementation of Radio Frequency Identification (RFID); An Exploratory Study into the Preparedness of Retailers", 1st International Academic and Technical Conference, Oxford.

Brown, A. and Bakhru, A (2006), "Theories of Technology Adoption and the Case of RFID", 13th European Conference on Information Technology Evaluation, September 2006.

Brown, I. and Russell, J. (2007), "Radio frequency identification technology: An exploratory study on adoption in the South African retail sector", *International Journal of Information Management*, Aug 2007, Vol. 27, Issue 4, p250-265.

Chao, C.C., Yang, J.M. and Jen W.Y. (2007), "Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005", *Technovation*, May 2007, Vol. 27, Issue 5, p268-279.

Curtin, J., Kauffman, R. and Riggins, F. (2007), "Making the 'MOST' out of RFID technology: a research agenda for the study of the adoption, usage and impact of RFID", *Information Technology & Management*, Jun 2007, Vol. 8, Issue 2, p87-110.

Del Aguila-Obra, A.R. and Padilla-Melendez, A. (2006), "Organizational factors affecting Internet technology adoption", *Internet Research*, 2006, Vol. 16, Issue 1, p94-110.

Durkin, M., Jennings, D., Mulholland, G. and Worthington, S. (2008), “Key influencers and inhibitors on adoption of the Internet for banking”, *Journal of Retailing & Consumer Services*, Sep 2008, Vol. 15, Issue 5, p348-357.

Fichman, R.G. and Kemerer, C.F. (1999), “The Illusory Diffusion of Innovation: An Examination of Assimilation Gaps”, *Information Systems Research*, September 1999, Vol. 10, Number 3, p255-275.

Hoske, M. (2004). “RFID: Adoption increases despite costs”, *Control Engineering*, July 2004, Vol. 51, Issue 7, p46-47

Hossain, M.M. and Prybutok, V.R. (2008), “Consumer Acceptance of RFID Technology: An Exploratory Study”, *IEEE Transactions on Engineering Management*, May 2008, Vol. 55, Issue 2, p316-328.

IMDA (2008),

http://www.ibec.ie/ibecweb.nsf/wvBusinessSectors/Irish_Medical_Devices_Association?OpenDocument, accessed 17/08/2008.

Jones, P., Clarke-Hill, C., Shears, P., Hillier, D., and Comfort, D. (2004). “Radio frequency identification in retailing and privacy and public policy issues”, *Management Research News*, 2004, Vol. 27, Number 8/9, p46–56.

Jones, P., Clarke-Hill, C., Hillier, D. and Comfort, D. (2005) “The benefits, challenges and impacts of radio frequency identification technology (RFID) for retailers in the UK” *Marketing Intelligence and Planning*, 2005, Vol. 23, Number 4, p395-402.

Kennedy Group (2008), <http://dcm-abs.blogspot.com/2008/01/radio-frequency-identification.html>, accessed 21/08/2008

Kumar, S., Pauly, S. and Budin, E. (2007) "Impact of radio frequency identification technology on manufacturing and logistics: challenges and issues", *International Journal of Manufacturing Technology and Management*, 2007, Vol. 10, No. 1, p57-70.

Letti, C. (2008) "Exploring How Lead Users Develop Radical Innovation: Opportunity Recognition and Exploitation in the Field of Medical Equipment Technology", *IEEE Transactions on Engineering Management*, May 2008, Vol. 55 Issue 2, p219-233.

Li, S., Visich, J., Khumawala, B., and Zhang, C. (2006) "Radio frequency identification technology: Applications, technical challenges and strategies", *Sensor Review*, Vol. 26, Number 3, p193–202.

Lunsford, D.A. and Burnett, M.S. (1992), "Marketing Product Innovations to the Elderly: Understanding the Barriers to Adoption", *Journal of Consumer Marketing*, 1992, Vol. 9, Number 4, p53-63.

Ngai, E.W.T., Moon, K.K.L., Riggins, F.J. and Yib, C.Y. (2008), "RFID research: An academic literature review (1995–2005) and future research directions", *International Journal of Production Economics*, Apr 2008, Vol. 112, Issue 2, p510-520.

Paxar Americas Inc. (2004), "RFID Basics", Whitepaper.

Reiner, J. (2005) "RFID in healthcare", *Healthcare Purchasing News*, June 2005, Vol. 29, Issue 6, p74-76.

Schmitt, P., Thiesse, F. and Fleisch, E. (2007) "Adoption and Diffusion of RFID Technology in the Automotive Industry", 15th European Conference on Information Systems (ECIS 2007).

Sheffi, Y. (2004), "RFID and the Innovation Cycle", *International Journal of Logistics Management*, 2004, Vol. 15, Issue 1, p1-10.

Shim, J.P. (2007), "An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry", *European Journal of Information Systems*, Dec 2007, Vol. 16, Issue 6, p712-724

Saunders, M., Lewis, P. and Thornhill, A. (2007) "Research Methods for Business Students", Fourth Ed., Financial Times/Prentice Hall, Harlow, England New York

System Label (2008),

<http://www.systemlabel.com/menu.aspx?menu=42&parent=0>, accessed 17/08/2008

Vail, P. J. and Agarwal, N (2007) "Disruptive innovation offers far-reaching solutions", *IEEE Potentials*, 2007, Vol.26, Number 2, p25-29.

Wu, N.C., Nystrom, M.A., Lin, T.R. and Yu, H.C. (2006), "Challenges to global RFID adoption", *Technovation*, Dec 2006, Vol. 26, Issue 12, p1317-1323.

Appendix 1 - Questionnaire

Questionnaire - RFID Adoption in the Irish Medical Devices Sector

Date: _____ **Name:** _____

Job Title: _____

Company Name: _____

Confidentiality: Do you wish to keep either your name, or that of your organisation, confidential in the final submitted thesis? **(Please tick one)**

YES []

NO []

No. of employees: (Please tick one)

1-100 []

101-499 []

500-999 []

1,000-9,999 []

More than 10,000 []

Please describe the nature of your company's business:

Which of the following most accurately describes the products you manufacture? (Please tick one)

Low volume, low cost []

Low volume, high cost []

Medium volume, low cost []

Medium volume, high cost []

High volume, low cost []

High volume, high cost []

Other? (Specify) []

Which of the following statements best describe your company's current involvement with RFID technology?

(Please tick one)

We have not considered RFID yet []

We have spoken informally about RFID []

We have formally investigated RFID []

We are planning to launch a RFID pilot []

We are currently running a RFID pilot []

We have completed a pilot and will not be implementing RFID []

We have completed a pilot and are planning to implement RFID []

We are currently implementing RFID []

Other: (Specify) []

(S.2) For each of the following statements please tick the box that matches your views most closely:

(S2.1) RFID technology offers, or has the potential to offer, your organisation significant benefits over traditional barcode identification technologies.

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.2) RFID technology is consistent with your organisations strategic intent, infrastructure, practices and needs.

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.3) The complexity of implementing RFID technology is not an issue for your organisation.

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.4) The cost of implementing RFID technology is justified by the benefits to be received

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.5) The top management team in your organisation is pro-actively supporting and leading the drive for RFID implementation

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.6) Your organisation has sufficient internal IT expertise to implement, integrate and maintain RFID

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.7) There are sufficient resources within your organisation to experiment with and pilot RFID technology if appropriate

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.8) Your organisation is capable of and willing to adapt your business processes in order to aid RFID implementation

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.9) Adoption of RFID technology within your organisation is, or will be, accelerated by what your competition is doing in this regard

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.10) There is sufficient external support and after sales service available from vendors and manufacturers to maintain RFID systems

Strongly Agree Agree Not Sure Disagree Strongly Disagree

(S2.11) Industry and standards bodies, such as the FDA, will heavily influence your organisations adoption of RFID technology

Strongly Agree Agree Not Sure Disagree Strongly Disagree

Appendix 2

Semi-Structured Interview Questions and Prompts

1. Technological Context:

1.1. Compatibility:

1.1.1. Def: “Degree to which technology is perceived to be consistent with an organisations strategic intent, infrastructure, practices and needs”

1.1.2. Does organisation have flexible IT infrastructure that can accommodate RFID systems

1.1.3. Can hardware, software and data resources mesh and integrate seamlessly with existing IS resources?

1.2. Complexity:

1.2.1. More complex than barcodes to implement. Agree?

1.2.2. Organisations migrating to RFID might have to accept dual environment with both barcode (at item level) and RFID tags (at pallet/case level) for some time. Agree?

2. Organisational Context:

2.1. Top management attitude:

2.1.1. Attitude and support?

2.1.2. Business process changes required?

2.1.3. Overcoming resistance to change?

2.2. IT expertise:

2.2.1. Is skilled IT expertise available?

2.2.2. Cross-functional teams?

2.3. Organisational size:

2.3.1. Large organisations have more resources for pilots, etc.

2.3.2. Smaller organisations have less resources

2.3.3. Smaller organisations have less power to influence their suppliers

2.4. Organisational Readiness:

2.4.1. Is organisation prepared to make business process changes?

2.4.2. Sites need to make adjustments if benefits are to accrue. Is this possible?

2.4.3. Cultural willingness to move beyond traditional methods needs to be developed to ensure implementation. Does this exist?

3. Environmental Context:

3.1. Competitive pressure:

3.1.1. What are competitors doing?

3.1.2. Can you afford to let them get ahead?

3.2. External support:

3.2.1. Do you rely on external support (if IT expertise not in-house)?

3.3. Change agents:

3.3.1. Vendors selling technology?

3.3.2. Government and industry bodies promoting adoption of technology?

3.3.3. Role of standards bodies?

3.3.4. Industry and regulatory pressures for standards?

3.3.5. Tagging Mandates?