Department of Information Technology

An investigation into the nature and extent of the adoption of RFID in the KwaZulu-Natal Province of South Africa

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Abstract

Radio Frequency Identification (RFID) allows for the wireless transfer of data between a small electronic transmitting tag and a reader without the necessity of line-of-sight. A feature of RFID, is that this read operation may occur over long distances and that multiple reads may occur. The aim of this study is to analyse the nature and extent of RFID adoption in the KwaZulu-Natal Province of South Africa.

The study fits within the theory of innovation diffusion and is concerned with issues around technology diffusion, adoption rates, and its associated critical success factors. The estimation of RFID diffusion rate in the study is based on a telephonic survey of 140 companies. The respondents were chosen from a marketing database that had extensive information on South African companies. Size was determined to be the selection criterion as the literature indicates that size is the most compelling concomitant to innovativeness. In this study, size was deemed to be companies that had more than 50 PC's in one geographic unit, of the company, in KwaZulu-Natal.

The key research result locates the RFID diffusion rate in KwaZulu-Natal to be around 19% which corresponds to points beyond the "chasm" as defined by innovation diffusion theory.

The second phase of the study comprised the administration of a questionnaire to two groups of IT professionals with the aim of comparing perceptions and other characteristics between the two groups. The 140 respondents were asked to submit as many professional staff as they could for an in-depth interview. The result was that 21 companies submitted 30 candidates. This yielded the two groups: the Adopter sample with 14 respondents, and the non-adopter sample with 16 respondents.

The analysis of results shows the two groups have similar views on many strategic factors such as privacy, security, cost and standards etc. Adopters perceive that the following factors impacts RFID adopting decisions more (than non-adopters): Turnover, Having labour cost savings, RFID ubiquity, It will take as long for my company to adopt RFID as it did for barcode, RFID cost awareness. On the other hand non-adopters felt that the following factor impacts non-adoption of RFID Technology unproven or immature, Human skills non-availability, Implementation costs, Corporate resistance, and, Support Concerns.

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Acronyms

ACSA	The Airports Company of South Africa
AFC	Automatic Fare Collections
Auto-ID	Automatic Identification
CASPIAN	Consumers against Supermarket Privacy and Numbering
CEI	Computer Ethics Institute
CIO	Chief Information Officer
CPP	Citations per Publication
CSIR	Council for Scientific and Industrial Research
DOD	United States Department of Defence
DOI	Diffusion of Innovations
EAS	Electronic Article Surveillance
EDI	Electronic Data Interchange
EPC	Electronic Product Code
GDS	Global Data Synchronisation
GPS	Global Positioning System
HF	High Frequency
ICT	Information and Communication Technology
IFF	Identify Friend or Foe
ISM	Industry, Scientific and Medical
ISO	International Standards Organisation
JIT	Just-in-Time
LF	Low Frequency
MF	Microwave Frequency
OECD	Overseas Economic Corporation Development
POS	Point of Sale System
ROI	Return on Investment
RFID	Radio Frequency Identification
SARS	Severe Respiratory Syndrome
SCM	Supply Chain Management
SKU	Stock-keeping Unit number
TALC	Technology Adoption Lifecycle Model

Chapter One
Introduction

1.1 Background

Radio Frequency Identification (RFID) is a generic term that is used to describe a system that wirelessly transmits the identity of an object or person in the form of a unique number to a reader, by using the medium of radio waves (Roberti, 2005).

RFID allows for the wireless transfer of data between a small electronic transmitting tag and a reader without the necessity of line-of-sight. A feature of RFID is that this read operation may occur over long distances and that multiple tags may be read and data exchanged virtually simultaneously. The data transfer occurs by using airwaves and the data size transferred is typically up to 2KB, although higher transfer rates are possible. Radio Frequency Identification (RFID) belongs to a class of automatic identification techniques called Auto-ID. Auto-ID includes, *inter alia*, Bluetooth, barcodes and biometric systems (Finkenzeller, 2003).

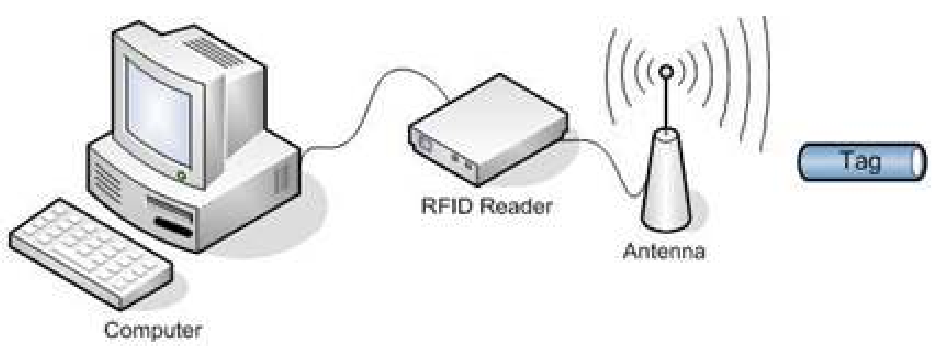


Figure 1.1 A basic RFID system

Note the figure is not to scale for illustration purposes.

Figure 1.1 (not to scale) shows a tag which is usually on an item. The tag broadcasts information which is picked by an appropriately tuned interrogator usually called an RFID reader. The reader in Figure 1.1 has an antenna. If the reader has the appropriate decryption software, it can make sense of the data read from the tag and send this data to a server for further processing.

The wireless, non-line-of-sight, simultaneous read properties of RFID make it extremely useful in many areas of applications that require barcode type identification. It also works well in hostile environmental conditions such as extreme temperatures, dirty or radioactive environments where better known Auto-ID technologies like barcode may fail (Finkenzeller, 2003). RFID tags are also known to be much more difficult to counterfeit than other Auto-ID technologies (Roberti, 2005b).

RFID has been called a "barcode replacing technology" (Marsh, 2005) and "barcode on steroids" because of the theory that with appropriately placed antennas and transponders (tags) on an item it is possible to track the following lifecycle of a product: manufacturing, distribution, disposal, and recycling. This can happen across the entire supply chain thereby providing a real-time video of product movement instead of a snap-shot as it is done with barcode and other stock taking technologies (Bonner, 2007). Although barcode has only been in commercial use since 1974, RFID is a grand though active retiree (Thakur, 2007) as it was first used in 1944 in World War II. Albrecht (2003) sinisterly calls RFID the "mark of the beast" in a creative reference to the Christian belief emanating from the Book of Revelations that it is improper to tag humans by the sub-dermal insertion of RFID chips.

The negative connotation of tagging may also be contextualised by the infamous tagging of Robben Island prisoner Nelson Mandela as 46664 and the savage historical tagging of black slaves. In addition there are some technological, economic and societal issues that mitigate against RFID's adoption. It should be noted that RFID is not yet a mature technology and there are still a number of issues that remain to be resolved. Finkenzeller (2003), for example, suggested that some of these issues are: the effect of metal and liquid on RF transmission, the lack of standards, and the fact that the amount of data generated could congest networks.

Yet the hype around RFID as a technological marvel continues unabated. In fact, a point is now being reached where the price and performance of the tags is generating interest for the use of RFID in Supply Chain Management, Asset Management, Healthcare and other areas.

RFID has made for great mainstream press in the last few years. This interest in RFID stems from significant individual orders placed by brand leaders. In particular, Gillette placed an order for 500 million tags in 2003 and Benetton similarly placed an order for 15 million tags (Boycott Gillette, 2003). These are certainly noteworthy orders but what really made the press was the subsequent scaling down of the scope of the projects for reasons that were *not* due to cost or implementation failure but rather due to pressure from consumer groups who feared an invasion of privacy (Albrecht, 2003).

At the same time, there has been a noticeable increase in patents and product releases with a corresponding increase in research publications on RFID.

1.1.1 Current RFID Applications

Some interesting applications of RFID have occurred in the following domains:

- **Leading Chain Stores** like Wal-Mart, Marks and Spencer, TECSO and Metro have asked their top 100 suppliers to use RFID at pallet level since 2005. It is practical to point out that South Africa did have the technology albeit at prototype stage to use RFID and demonstrated this in a shopping mall in 1994. Here it was demonstrated that a shopper can load a trolley, push it through an RFID-enabled pay-point, and receive an annotated till-slip, *without* empting the trolley and paying for it (Marsh, 2005).

- **Livestock** are tagged in countries such as Botswana and Australia to enable the tracking of animals from birth to slaughter. This is especially useful given the recent prevalence of mad-cow disease, foot-and-mouth disease, swine fever, ostrich flu and quinine flu. Countries with relevant RFID systems for livestock management are usually allowed to export meat products during such outbreaks, with only selective embargoes, whereas countries like South Africa face almost total export bans. In a farm setup, RFID also helps neighbouring farmers to identify strays. It also deters rustlers who now have a more difficult time concealing theft (Thakur, 2007:b).

- **Automatic Fare Collections** (AFC) applications use RFID at toll roads with systems like EZ-Pass, FastPass, IPass, PayPass and SpeedPass (Reiback *et al.*, 2006) and at petrol stations with EasyFuel. In toll roads a vehicle-mounted transponder antenna is activated by an antenna on a toll lane. The antenna identifies the owner's transponder and reads the owner's account information, from where a toll deduction is made (Bonner, 2007).

An innovative company, OTI, together with Petrol Stations, developed a product that the South African Government and many companies use. It integrates RFID with EDI and it provides company employees with a paperless, cashless petrol (gas) filling mechanism. Here an RFID tag is placed on the petrol tank of each vehicle. Readers are then placed on the tip of the Petrol nozzle at participating petrol stations. As long as wireless communication between the vehicle and the nozzle is maintained, fuel can be dispensed. This controls fuel type and eliminates cross contamination. It also eliminates card fraud and unauthorized fuelling. The commercial product is called EasyFuel (Asec Report, 2008).

- **Vehicles** have been using RFID for over a decade as an added security feature to the traditional lock and key. This is achieved through the combination of a tag and RFID reader. In fact, the first RFID patent was a similar device (Schmitt, 2007). The added cost and complexity of an RFID tag and reader in the car ignition key explains why replacing such a lost key is neither trivial nor cheap.

- **Sporting Events** like the 2006 FIFA soccer World Cup (3.1 million tags), the Boston Marathon (40 000 tags), and the Comrades marathon (13 000 tags) use RFID to track large numbers of sportsman and spectators. The Comrades marathon is an interesting case. The sheer number of 13 000 competitors and the 90 km length of the race lends itself to cheating. A cheating father and son have been banned for life by the Comrades Marathon Association after they were found guilty of fraudulently obtaining recognition for completing the race in 2002 and 2003 when the father ran the race with two RFID tags, one belonging to him and the second belonging to the son. After investigation, there were several pictures of the father but none of the son, yet their split times were identical (Thakur, 2008 and Khan, 2004).

  The researcher's children participated, along with 17 000 other swimmers, in the 2008 Midmar Mile Open Water, the world's largest such event, with RFID bracelets attached to their ankles. Their results were out as soon as they left the water to the delight of their pensive, but dry parents. An hour later their exact swim time, determined as the time they actually entered the water to finish time, was released. This reduced the son and the daughter's swim time by six minutes and by three minutes respectively.

- **Retail Operations** in South Africa have demonstrated the technology to use RFID in a shopping mall in 1994. Here it was shown in a live television simulcast that a shopper can load a trolley, push it through an RFID-enabled pay-point, receive an annotated till-slip, *without* emptying the trolley and paying (Marsh, 2005). This idea has, however, still not permeated mainstream business. It has not replaced or even supplanted barcode in South Africa. However, there are several instances of RFID stores in the world (Bitko, 2006).

- **Hospitals** such as Alexandra Hospital in Singapore are using RFID in the wake of the Severe Respiratory Syndrome (SARS) virus outbreak in 2003. All visitors, patients, doctors and staff entering the hospital are issued a card embedded with an RFID chip, so if they are later diagnosed with SARS, a record of all other individuals with whom that person had contact can be immediately determined (EPC Report, 2008). This ensures that only the people that may be infected are isolated and not the entire hospital, which needs to remain open for other emergencies. In South Africa, RFID is being used to track patients and track hospital assets (Wavetrend Website, 2008).

- **The Library System** can benefit from RFID by enabling the storing, automatic issuing (lending), returning, and restoring "lost" books to circulation. This will free librarians to do more knowledge management than book sorting.

  As a child the author used to hide Hardy Boys books with the Nancy Drew section in the school library to ensure that he had a continuous supply of this boyhood thriller. The books were not stolen but hidden. Karen Saunders of the Santa Clara City library reports a similar scenario with many DVD's being hidden by patrons for their own use later. Using the RFID reader, staff located these lost items and restored them to circulation (Bowen, 2004).

- **Mining** uses RFID to track people, assets and commercial explosives such as dynamite in a hostile environment. For example, RFID has one useful "sniffer dog" type application that averted a disaster. This occurred at a South African mine at Paardekraal where miners were given active tags to track-and-trace them should they be unable to respond. When the last cab was returning to ground level for a planned blast, it was found that one tag did not "checkout". A search resulted in the disoriented miner being rescued (Ipico Report, 2006).

1.1.2 Future Applications

There is much excitement about the scope and range of innovative systems that are possible with RFID. The section considers some emerging and future applications in RFID.

- **Anti-document counterfeiting devices** has been researched by Conring researchers who developed a tiny coded bead that is invisible to the naked eye, which may be embedded in inks to tag currency and other documents. This may be added to paint, or explosives, or any other products that law enforcement officers have a strong interest in tracking (Cavoukian, 2004:9).

- **Smart Cooking** makes use of RFID reader in a microwave. Cooking instructions are written into an RFID tag attached to a pre-cooked TV dinner. This cooking instruction could be, for example, an operating instruction that would start a defrost cycle and then grilling cycle for a meal, and then a warming cycle without human intervention (US Patent 6953919, 2005).

- **Luggage** loss and delays are a source of great frustration to millions of weary travellers who find themselves far away from home without their luggage. By using RFID on luggage one can tell on what one's flight a baggage should be, where it came from, and its intended destination. In the case where a flight is diverted, RFID can help to update the luggage information with the new flight destination(s) without manual intervention. The absence of human intervention simultaneously reduces theft and errors.

  Hong Kong Airport has piloted and implemented a passenger luggage tracking system using Gen2 RFID tags from Intermec, in a project that has thus far cost 50 million Hong Kong dollars. The airport claims a luggage read rate success of 97% versus 80% with barcodes. They currently use RFID tags on 40 000 pieces of luggage each day. This is the world's fifth largest airport with 35 million tons of luggage per annum (Hong Kong Press Release, 2008).

- **Passports**, specifically new US passports, will soon be read around the world, by means of embedded RFID tags. The tag will on command broadcast an individual's name, address and digital photograph. Kelly Shannon of the USA State Department commented that "this makes passports more secure" and "is yet another layer beyond the security features we use to ensure the bearer is the person who was issued with the passport originally" (Singel, 2004).

- **Near Field Communication** is a short-range wireless communication that may be initiated between two very close communicating devices. This was pioneered by a consortium of Nokia, Philips and Sony. One or both sides are currently a cell-phone. This technology currently allows cell-phone users to retrieve timetables from a bus stop, to access a promotional website by simply holding the cell-phone next to the commercial poster containing an RFID chip. Users share data such as ring tones, contacts and so on by simply holding the devices against each other. This communication mode is opened when the distance between two NFC devices is reduced to almost zero. A commercial phone with an embedded RFID reader is already available from Nokia (Plaggenborg, 2006).

- **Container Loading and Unloading** is a South African patent that involves harbour logistics**.** An RFID reader is mounted on a ship's crane hoist which automatically identifies a container when it picks or drops the load in a harbour. This prevents erroneous or fraudulent container loading or off-loading from ships. The innovation is that this loader is ship based and comes with a special container holder for less well-equipped harbours in Africa thereby improving accessibility (SA Patent, 2006).

It is apparent that there are many potential uses of RFID. A cautionary note is that RFID proponents and vendors may be guilty of overselling this product with too many promises of its potential.

1.1.3 RFID Challenges

According to Potter (2005) RFID is the least understood and the most feared of the wireless technologies. Consumers are afraid of being tracked by the product they carry. Travellers are afraid of privacy issues and identity theft. Businesses are worried about keeping hackers at bay. Of course, they worry more that by walking through their store the opposition may, with an appropriate rogue reader, poach their current stock data (MOST Journal, 1995).

The advocacy group called CASPIAN (Consumers against Supermarket Privacy and Numbering) is vehement against RFID usage at item level in stores. It was in response to action by this group that in 2003 Gillette and Benetton respectively scaled down initial orders of 500 million and 15 million RFID tags (Cavoukian, 2004:15).

The fatal error for Gillette was that it exploited a pilot project to get photographic information of the consumers as soon as they picked their Gillette product off the shelves in the stores. Gillette did not inform consumers that it was monitoring their purchasing habit. This is invasion of privacy (Boycott Gillette, 2003).

Perhaps it is in response to these sorts of privacy concerns that the Airport Company of South Africa (ACSA) - (responsible for all airports and the movement of 30 million passengers) annually, is awaiting guidance from the Constitutional Court over "invasion of privacy" issues when it comes to tracking passenger baggage using tags (Sunday Times, 2006).

RFID also proposes a new type of environmental threat. A tag is an electronic artefact with silicon and circuitry. It is therefore very possible that if every item has an RFID tag our garbage will be full of electronic waste. This will have deep implications for our garbage disposal and landfill processes. The South African government has legislated that all electronic waste is disposed in an environmentally sensitive manner.

RFID tags are costly with unit prices ranging from 20c to a few dollars. The unit tag prices are subject to a price sensitive curve. The common discussion in 2005 and 2006 has been the 5c tag. This has been the holy grail of RFID (Roberti, 2007). Avery Dennison has reported costs of tags at 7.6 cents for orders of more than a million tags (Harrop, 2006).

In short, antagonists of RFID have perpetuated many fears and myths - some justified, some not.

1.1.4 Size of the Market

There are various estimates as to the size and scope of the RFID market. The current size is estimated at 6 billion tags. Certainly capacity does not appear to be a problem as company Alien Technologies has developed a chip-making technology to make dust-sized RFID microchips. The capacity of this plant is 80 billion chips per annum (Daniel-Hunt *et al.*, 2007:20).

Daniel-Hunt *et al.* (2007) optimistically expected the market by revenue to have been $7.5 billion in 2006. They also said that sales of tags to Wal-Mart's top 100 suppliers alone could reach one billion tags. However, the market value was only $4.96 billion in 2007 (Harrop, 2008).

Harrop (2008) also found that the largest current RFID project is the Chinese RF ID card (sic) which is spending about $2 billion in supplies and infrastructure in China.

The largest single order in the US was by the Department of Defence. It was valued at $425 million with Savi Technology (Savi Report, 2006). In the past fifty years, approximately 1.5 billion RFID tags have been sold worldwide. Sales for 2007 alone were expected to exceed 1 billion and as many as 1 trillion could be delivered by 2015 (Harrop, 2008).

Table 1.1 RFID case studies by country and number (Harrop, 2006)

Country	Number of case studies
Australia	40
Canada	55
Korea	60
Netherlands	60
France	75
China	80
Germany	100
Japan	140
United Kingdom	220
United States	630

The relative frequency of case studies by country alludes to a growing international interest in RFID.

25 million passport tags were sold in 2006 (Harrop, 2006). The current demand for passport tags is about 40 million per annum even though unit costs of passport tags are still in dollars. The passport tags are ISO accredited and use the ISO 14443 specifications (Harrop, 2006).

Harrop (2006) reports that Phillip Morris and the China National Tobacco Monopoly together ship 63 billion packets of cigarettes per annum and would want to use RFID primarily against counterfeiting.

The discussion until now introduced RFID and suggested some current and future areas of application in RFID. Chapter Two would undertake a detailed review of RFID and the research generated around RFID by conducting a literature review. It begins by building knowledge of RFID, its operating frequency, standards, issues, concerns and areas of promise.

The next section introduces a theory that will help us to understand why and how new technologies are adopted or not.

1.1.5 Diffusion of innovations

Some inventions take the world by storm (archetype: 'the Sony Walkman'). Others seem to fail, lie dormant for decades, but when their time comes, their use grows quickly, even explosively (archetype: the fax machine). Most achieve slow penetration at first, and then their adoption grows more quickly, but later slows down again (Clark, 1999). The interesting question is to find how RFID will diffuse as an innovative technology.

There is a broad theory called the Diffusion of Innovations (DOI) that purports to describe the patterns of adoption, explain adoption mechanisms, and assist in predicting whether and how a new invention will be successful (Rogers, 1983:5). Rogers (2003) defines **diffusion** as the process in which an innovation is communicated through certain channels, over time, among the members of a social system. He categorises technology adopters into five adoption groups depending on when they took the adoption decision: Innovators, Early Adopters, Early Majority, Late Majority and Laggards.

- **Innovators** or technology enthusiasts are the experimenters who are willing to take a risk on a good idea.

- **Early Adopters** are younger, more educated and tend to be community leaders. They purchase prototypes, convert these into turnkey solutions and sell them.
- **Early Majority** are also younger, educated folk, who tend to be community leaders. However, they are risk averse and stay away from “bleeding-edge” technology.
- **Late Majority** are older, less educated, fairly conservative and less socially active. They will adopt an innovation only when the majority has done so.
- **Laggards** are very conservative, have low capital, and are the least educated. They either never adopt an innovation or are the last to do so (Rogers, 2003).

1.1.6 Moore’s Technology Adoption Curve

The work of Everett Rogers on the diffusion of innovations was refined by Geoffrey Moore’s theory and has received widespread respect and attention. It is now used commercially to gauge the relative progress of a technology adoption (Moore, 1991 and 1999).

Moore accepts that Rogers’ normal bell-shaped curve typifies the adoption of a new innovation, but he introduces the concept of a chasm to the curve. This is explained in Figure 1.2.

The **chasm** is the “make-or-break” point in the sense that technologies that have crossed the chasm are ensured of a sustained diffusion success. On the other hand, technologies that have failed to reach the chasm are ensured of a sustained diffusion failure. This is where that big gap or chasm exists. It is here that a technology can either become entrenched or disappear from the market space due to non-adoption.

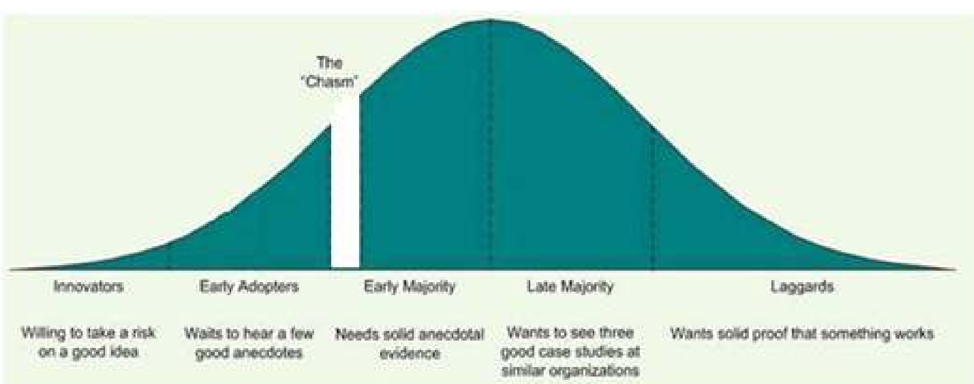


Figure 1.2 Moore’s Bell Curve Diagram modified (Dr Dobb’s, 2006)

Moore's research (1999) determined that the chasm is between the early adopters and the early majority. This figure is a modified version of Dr Dobb's contribution (2006) as the original was slightly incorrect due to the chasm being placed in the Early adopter segment.

Chapter Three reviews existing literature on Diffusion of innovations. It examines the technology adoption curve and how four authorities in the field, Rogers, Moore, Norman and Von Hippel, look at the curve. It then discusses Diffusion of innovations theories. It tries to use these theories to understand how RFID has progressed. **Chapter Four** reviews the Diffusion and Adoption research that has been conducted along with RFID.

1.2 Problem Statement

The Problem Statement is "Developing countries like South Africa usually import and utilize technology massively but that trend does not seem to apply to RFID. This is telling in the context of South Africa, which is the world's fourth largest importer of technology. The perceived slow rate of adoption is therefore studied by considering companies that use, have used or commit to using RFID."

According to the Organisation for Economic Corporation and Development (OECD), South Africa is the world's fourth-largest net importer of technology (Giddings, 2005). This dubious distinction apparently does not reflect in the adoption of RFID, as may be found by a preliminary literature review and anecdotal evidence. It is in this context that the perceived slow rate of RFID adoption, in the South African market, is telling.

Yet some local companies have either piloted an RFID project, adopted RFID or have decided on a time frame to adopt RFID. A short conversation with a senior technical manager of one of the major cellular phone network in South Africa was dismissive: "RFID won't work - too many privacy issues." A senior manager of a South African government ICT agency was equally non-committal; "we will use it when we believe that it is a main stream technology" (Personal Communication, 2006). As previously mentioned the Airports Company of South Africa is awaiting guidance from the Constitutional court before they adopt RFID to handle baggage (Sunday Times, 2006). Other stakeholders mentioned cost, lack of skills and various other reasons as explanations for non-adoption. International literature reveals similar issues being of concern.

1.3 Research Goals and Sub-Goals

This study analyses the adoption of RFID technology in organisations in KwaZulu-Natal.

It seeks to

a) *Determine the RFID diffusion rate in the research population.*

The research question of interest with respect to RFID is simple: "Will RFID be used by industry and become mainstream?" This question is non-trivial. Therefore tools like Rogers' Diffusion Theory (1983) and Moore's Technology Adoption Curve (1999) among others are used to answer this question.

b) *Analyse differences in organisational characteristics between RFID adopters and non-adopters companies.*

The literature alludes to many reasons as to when and why a decision to adopt a technology like RFID is taken. This question looks at organisational characteristics of adopters and non-adopters respectively and compares them.

c) *Analyse differences in perceptions between RFID adopters and non-adopters companies.*

This question examines the perceptions of the two categories towards factors that may influence these reasons. It will tell us why adopters adopt and the converse. This local experience or result will be compared with existing literature determine global relevance. The answers will contextualise RFID adoption.

1.4 Research Questions

The research attempts to answer the following research questions:

a) *What is the diffusion rate of RFID?*

   The research seeks to determine where RFID is on Moore's Technology Adoption Curve.

b) *What characteristics of companies influence the perceived adoption of RFID? To what extent do the perceptions of RFID adopters differ from the perceptions of RFID non-adopters?*

This question draws on various characteristics from a review of the available literature and tests their responses within both adopter and non-adopter categories. The result is then analysed for similarities and differences.

c) *How do decision makers perceive the attributes such as relative advantage, compatibility, complexity, trialability, and observability of the RFID innovation?*

This research question examines the perceptions to determine which variables positively influence an adoption decision or, conversely, which variables influence a non-adoption decision.

1.5 Research Hypotheses

If RFID were a silver bullet the adoption rate should be very high. Anecdotal material, casual media study and the literature review suggest it is not. The adoption of RFID needs understanding and study. In order to do this one must have some idea of the adoption pattern. This research therefore proposes that:

a) *RFID is currently in the early majority stage of Moore's Adoption Curve but on the right hand side of the chasm as shown in Figure 1.2.*

b) *The size of a company, the nature of its business activities, and its strategic vision influence its RFID adoption decision.*

c) *There are issues on which RFID adopters and RFID non-adopters share the same view but on other issues their respective perceptions differ significantly.*

1.6 Motivation for the study

This study is opportune, timely, and relevant given the infancy of RFID. When the researcher commenced his work and subsequent research, there were, to his knowledge, only two reference textbooks on RFID in existence. They were *The RFID Handbook* by Finkenzeller (2003) and *Guide to RFID Compendium* (2002). At the time of writing (2008) there are over 25.

There have been conferences on RFID in just about every country in 2006 and 2007 but these were commercially or vendor driven. There were over 200 patents filed by RFID staff in one company alone (Mash, 2005). So there is massive scope for research in the commercialisation of RFID at developmental, application and integration levels.

The reasons for the adoption of any technology like RFID are to add value to a business process. For RFID this is a challenge due to factors like privacy, security, bandwidth, frequency, failed reads, physics, and environmental factors such as water, metal etc.

Harrop (2008) predicts that the sale and output of RFID tags in the next three years will exceed that of the previous sixty years. There is a realistic possibility that this technology will become as entrenched as the ubiquitous barcode. It may be a standard technology tool in Supply Chain Management. The RFID Journal has been writing increasingly confidently of the 5c tag ($0.05) (Roberti, 2007).

1.7 Scope and Delimitations

This study is based in KwaZulu-Natal, although parallels can be drawn with developed countries. It focuses mainly on the supply chain market. It consequently excludes the security market, which deals, *inter alia*, with access control and time management systems even though the security market is significant and well defined. In the security market RFID tags are used as contact tags, as immobilisers in vehicles, or as proximity switches, usually for the purpose of access control and asset management. But in the supply chain market RFID tags are used to track-and-trace inventory.

This is also not an engineering study so issues like attenuation, cross talk, impedance and other electronic or electromagnetic issues are noted but not pursued in this study.

For example, disregarding electronic or electromagnetic issues may be misleading. Sometime, in hospital environments, RFID may be used to track patients. An interference with some medical apparatus could be cause for concerns.

1.8 Research Methodology

A brief introduction to the research methodology is given in this section. However, **Chapter Five** describes, in detail, the Research Methodology for this study. It describes the research design, the tasks, procedures, and subjects. It also describes the conceptual and operational aspects of the independent, dependent, and the controlled variables.

Chapter Six does the analysis of data collected. The hypotheses are tested. The research outlining the objectives is addressed; the practical and theoretical implications of the research results are presented, as well as possible areas for future research.

1.8.1 Pilot Survey

This study focuses on corporate companies that operate in KwaZulu-Natal. The criteria used to determine the sample were companies that had at least 50 PC's in a geographic location. A telephonic interview was carried out with every company output from a database called Matrix Marketing. These companies were asked if they were currently using, not using, or had previously used RFID. They were also asked if they were prepared to participate in a questionnaire.

1.8.2 Questionnaire or Comprehensive Survey

A comprehensive questionnaire was undertaken to determine the impact, nature and extent of RFID usage in KwaZulu-Natal. In addition, interviews were also undertaken where respondents had difficulty filling in sub-sections of the questionnaire.

1.8.3. Interviews and Personal Communications

The researcher met and interviewed many experts and company vendors in RFID in order to establish a view of how the local RFID industry operates. This helped to plan the questionnaire.

1.9 Preliminary Literature Review

Finkenzeller (2003) is the most frequently cited academic author on RFID. The research area of adoption is dominated by the seminal series by Rogers in his books entitled "Diffusion of Innovations". This is also the most widely cited innovation diffusion study. In addition, Chao *et al.* (2006) have shown that the number of publications on RFID have grown significantly from 1991 to 2005 (Figure 4.1). This shows the growing academic research interest in RFID. An exhaustive literature review on the Adoption of RFID is given in **Chapter Four**.

1.10 Conclusion

This chapter introduces the study by providing a background for the diffusion of RFID, and by providing an overview of RFID applications and challenges. The objectives of the research are then presented along with its problem statement, the research questions and associated hypotheses, and the research methodology. Finally, the scope is delimited and an overview of the literature presented.

The content of subsequent chapters, namely Chapters Two to Five, is introduced in the appropriate sections. Chapters Six and Seven are dedicated to the research results and recommendations.

Chapter Two

Radio Frequency Identification (RFID)

2.1 Introduction

It is generally accepted that the first RF system was developed in the United Kingdom during World War II. A British team under Sir Robert Alexander Watson-Watt, who headed the secret project, conceived, designed and produced a transponder tag that was attached to each British plane in 1945 to distinguish returning British airplanes from pursuing in-bound German ones. This system called Identify Friend or Foe (IFF) generated a distinct "blip" on radar screens. The blip indicated that the aircraft posed no threat; otherwise it was fired upon (Takahashi, 2004). Advances in RF technology continued in the 1950's and 1960's with research focussed on how to use RF energy in anti-theft electronic surveillance systems. These are now called Electronic Article Surveillance tags (EAS) (Roberti, 2005a).

Charles Watson registered the first patent for an RFID tag in January 1973(Takahashi, 2004). This patent was for a passive transponder used to unlock a door without a key. This system comprised a card with an embedded transponder that communicated a signal to a reader near the door. When the reader detected a valid identity number stored within the RFID tag, the reader unlocked the door. This technology has been licensed to many companies such as Schlage (Roberti, 2005a).

This chapter explains the protocols behind RFID systems. These protocols include issues around the various types of tags, the RFID frequencies, the RFID standards, and the policies in an RFID ecosystem. The chapter ends with a comparison of barcode and RFID.

2.2 RFID Protocols

Before going into an in-depth examination of RFID protocols, it is important that a formal definition of RFID be given and that the context in which RFID operates as a system be explained.

2.2.1 Definition

Radio Frequency Identification (RFID) is a system that allows contactless monitoring, tracking and tracing of objects through an appropriate application technology. It is a generic term that is used to describe a system that transmits the identity of an object or person wirelessly in the form of a unique number using radio waves. It is grouped under the category of Automatic Identification Technologies or Auto-ID. The other familiar Auto-ID technique is barcode. A barcode is a strip of bars and gaps that represent numbers. Barcodes encode a number which is usually the stock-keeping unit number (SKU) and identify a class or type of product rather than a single unit (RFID+ Certification, 2006).

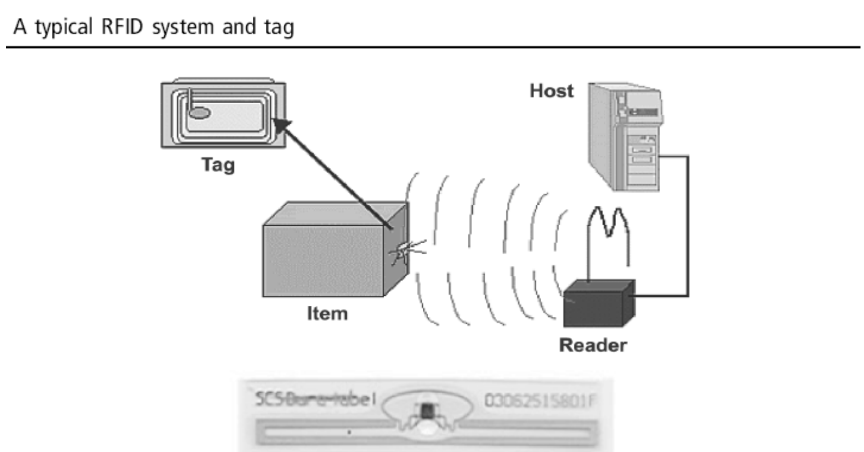
RFID tags are also called *smart labels* because of the special method namely radio frequency used to store and retrieve data from a device. An *RFID tag,* Figure 2.3, physically is an object such as a strip of wire, or an adhesive sticker, that can be attached to a product much like a barcode label. The RFID tag contains an *antenna* that enables it to receive and respond to radio-frequency queries from an RFID transceiver. The tag has memory for data storage (Finkenzeller, 2003).

The antenna is available in all kinds of shapes and forms in order to enable distant reads. The antenna may be placed on a warehouse door, for example, to receive data from tagged goods passing through (Mortensen and Pedersen, 2004).

2.2.2 A Basic RFID System

A basic RFID system comprises an antenna, a transceiver and a transponder (Finkenzeller, 2003).

Figure 2.1 shows an "Item" that has a "Tag" on it. The reader by way of the antenna picks up the presence of the "Tag", reads information from it and passes it to a "Host".



RFID Tag (not to scale)

Figure 2.1 A Typical RFID System and tag (Jones *et al*., 2004: 165)

The host is a computer or a server with the necessary hardware and software to accommodate an RFID reader. A discussion on RFID hosts is beyond the scope of this study.

Chapter one provided several examples of items used in existing or future RFID systems and no further discussion is carried out on such items in this chapter. This chapter focuses on the various elements of RFID systems: RFID tags, RFID readers, and the tags-readers communication.

2.2.3 RFID Tags

RFID tags come in many shapes and forms particularly as their range of applications increase, doubtless helped by the continual miniaturisation of transistors. Hitachi, a Japanese semiconductor company, reported a chip called the μ-Chip (pronounced mu-chip) tag that is 0.3 mm^2 and can hold 128 bits of data as shown in see Figure 2.2 (Cavoukian, 2004). Further, Hitachi has since announced a newer μ-Chip; which has the same operating characteristics as the one shown in Figure 2.2, but the chip is about 85% smaller than the pictured device, and is only 7.5 microns thick, which is small when compared to typical print paper thicknesses of 80 to 100 microns (Hara, 2006).

Most Auto-ID technologies, such as barcodes, only allow data to be input to a host system via a read operation. RFID, however, has the distinct advantage that it also allows the storage of data directly onto the tag itself via a wireless write operation (Dipert, 2004).

A tag must have an integrated circuit (silicon) and an antenna. There are two types of RFID tags: *active* and *passive* tags. The distinction is based on the source of energy, in the tag, that is needed to power the computer chip and antenna. A passive tag does not have a battery.

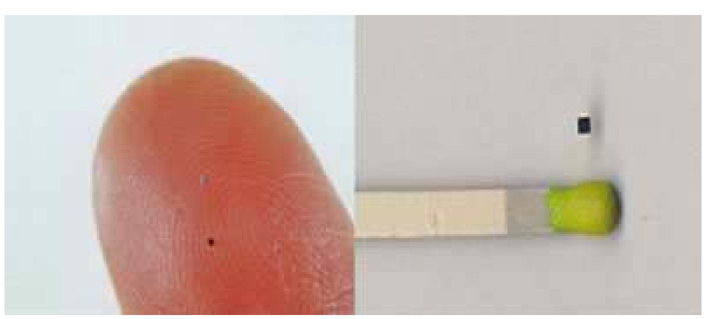


Figure 2.2 Hitachi μ-chip shown on a finger, and next to a matchstick (Bitko, 2006:18)

Figure 2.3 Picture of some RFID tags (Anon, 2006)

2.2.3.1 Passive Tags

These tags are often integrated with adhesive paper and have no power source. They have an antenna which serves for two-way communication *and* to capture power from the energy from the RF signal generated by the reader. This means that the tag is only powered when it is in the beam of the interrogator. A passive tag has a shorter read range (distances of less than 10 metres) and needs a powerful reader unlike an active tag (Cavoukian, 2004). As opposed to barcodes which use optical light and cables to transmit data, RFID tags transmit data through the air interface. The tags cost from $0.20 to a few dollars each.

2.2.3.2 Active Tags

These tags have their own power source (battery) and they continually broadcast their presence, even if no reader is present. The battery can (and will) run out of power. The battery makes active tags more costly than passive tags. These are also called *noisy tags*.

An active tag would broadcast its presence continually, sending packet after packet of information. A legitimate fear is the nightmare that RFID tags can clog network bandwidth.

2.2.3.3 Readers

RFID tags are interrogated by readers, which are in turn connected to a host computer. There are also two types of readers: active readers which operate with active tags only, and conversely passive readers which exclusively work with passive tags.

In a passive tag the RFID reader transmits an energy field that "wakes up" the tag and powers its chip, therefore enabling it to transmit and store data. Passive readers may cost up to $1 000 or even more.

Active tags periodically transmit a signal much like a lighthouse beacon even if there is no reader present and the active tags data may be captured by multiple readers, which must be handled appropriately. Active readers cost far less than passive readers.

Table 2.1 shows the technical differences between active RFID and passive RFID technologies (Auto-ID White Paper, 2006).

Table 2.1 Technical differences between Active and Passive RFID (Anon., 2002)

	Active RFID	**Passive RFID**
Tag Power Source	Internal to tag	Energy transferred from the reader via RF
Tag Battery	Yes	No
Availability of Tag Power	Continuous	Only within field of Reader
Required Signal Strength from Reader to Tag	Low	High (must power the tag)
Available Signal Strength from Tag to Reader	High	Low

2.2.3.4 Tag reader communication

By definition, the communication between an RFID reader and a tag happens by means of radio waves. As a security measure the information in the radio wave is usually encrypted. One should note that radio waves are not only used by RFID. Most modern communication technologies such as radio, analogue TV, Global Positioning System (GPS) and cellular phones also compete in this space alongside naturally occurring interferences from various sources such as weather conditions (rain, snow, and other types of precipitation) and electrostatic discharge (Lahiri, 2005; Finkenzeller, 2003). It is important to emphasise that although radio, analogue TV, Global Positioning System (GPS), cellular phones and RFID form the generic class of communication technologies, each has its own unique standards, specifications and protocols. For example, it is a misconception to state that RFID may be used as a GPS tracking device.

The following sub-sections deal with Operating Frequencies, Standards and the Policies around the Operation and Implementation of RFID.

2.2.4 Operating Frequencies

Frequency spectrum is arguably one of mankind's most precious resources. Some say that radio spectrum could be for the 21st century what oil was for the 20th century.

There are numerous battles and political fights over these allocations with billions of dollars involved. Jamming frequencies have even become a military tool. In the South African context Vodacom and MTN, the cell phone giants, are embroiled in a tussle with the ICASA (Independent Communication Authority of South Africa) to release more bandwidth for its explosive growth in cell phones (MyBroadband Article, 2008). This is why frequency spectrum as a finite resource is jealously guarded.

Figure 2.4 shows the frequency spectrum with the "radio range" expanded. The "RFID Frequencies" shown with the bold downward arrows refer to valid transmission ranges across the world for different tag types. It is explained in the next section.

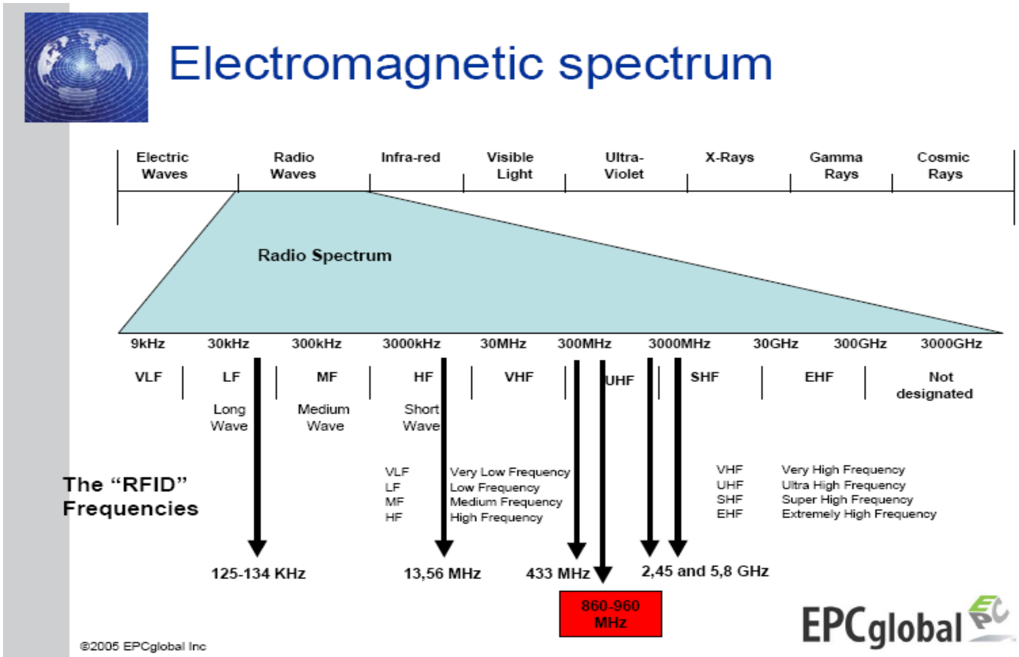


Figure 2.4 EPCglobal Frequencies and Standards (Barthel, 2005)

Low frequency (LF) is an established technology. LF typically does not allow multiple tags to be read simultaneously but is very tolerant of harsh operating conditions such as metal, liquid, dirt, snow or mud. LF RFID tags have a read range which is from a few centimetres to a couple of metres. It has low data transfer rates from tag to reader. Frequencies between 30 KHz and 300 KHz are considered low, and RFID systems commonly use the 125 KHz to 134 KHz frequency range. A typical LF RFID system operates at 125 KHz or 134.2 KHz (Lahiri, 2005; RFID+ Certification, 2006).

These are the most expensive tags. Due to the maturity of this type of tag, LF tag systems probably have the largest installed base. The LF range is accepted worldwide. Typical uses of RFID in LF include Animal identification and Car immobilisers (Lahiri, 2005; RFID+ Certification, 2006).

High Frequency (HF) is also an established technology. HF allows for multiple tags to be read simultaneously but is reasonably tolerant of operating conditions. The read range is up to one metre. Frequencies range from 3 MHz to 30 MHz, with 13.56 MHz being the typical frequency used for HF RFID systems. A typical HF RFID system uses passive tags, has a slow data-transfer rate from the tag to the reader, and offers fair performance in the presence of metals and liquids.

HF systems are also widely used, especially in hospitals, because this frequency does not interfere with existing equipment. Other uses of HF RFID are in Smart labels, Smartcards and Access Control. The HF frequency range is also accepted worldwide (Lahiri, 2005; RFID+ Certification, 2006).

Very High Frequency (VHF) is the next frequency range and it lies in the range between 30 and 300 MHz. None of the current RFID systems operate in this range. Therefore this frequency type is not discussed any further.

Ultra High Frequency (UHF) is the latest frequency range to be exploited technologically. UHF is gaining much attention because of performance and price. UHF allows for multiple tags (up to 200) to be read simultaneously but is less tolerant of operating conditions. The read range is up to four metres. There are no one-tag-fits-all categories as a system in UHF may have a short read range and another may have a long read range. The short range may either be viewed as an advantage or disadvantage. UHF ranges from 300 MHz to 1 GHz. A typical passive UHF RFID system operates at 915 MHz in the United States and at 868 MHz in Europe. A typical active UHF RFID system operates at 315 MHz and 433 MHz. A UHF system can therefore use both active and passive tags and has a fast data-transfer rate between the tag and the reader but performs poorly in the presence of metals and liquids. This is not true, however, in the cases of low UHF frequencies such as 315 MHz and 433 MHz. The typical use of UHF is in logistics (Lahiri, 2005).

Microwave Frequency ranges upwards from 1 GHz. A typical microwave RFID system operates either at 2.45 GHz or 5.8 GHz, although the former is more common. It can use both active and passive tags, has the fastest data-transfer rate between the tag and the reader, but performs very poorly in the presence of metals and liquids. The antenna of a passive tag operating in the microwave range has the smallest length, which results in a small tag size because the tag microchip can also be made very small. The 2.45 GHz frequency range is called the Industry, Scientific, and Medical (ISM) band and is accepted worldwide. The typical MF use lies in vehicle toll systems (Lahiri, 2005).

2.2.5 Middleware

Middleware is a necessary part of an RFID system. It acts as the interface between the RFID system and the applications with which the data must ultimately be integrated.

RFID tags significantly increase the amount and type of data available to an organisation. The ability to categorize, process, and even load balance that data is necessary for a good working solution. For example, what happens if RFID tag data is read twice? The middleware software can, in this case, act as the filter, clean up and synchronize the tag data, to make sure that duplicate tag data is not passed on to the application. The middleware software can also work to create an interoperable system, particularly when multiple vendors' product is involved. Tag data can sometimes be read incorrectly. Using embedded logic, middleware software can correct, aggregate, and filter the tag data. Middleware can also coordinate the activities of multiple readers. An example of this would be items or cartons with tags passing from the read range of one reader to that of another. Finally, middleware software can be the tool that enables the capture and review of tag activity within an organisation (Jilovec, 2004).

Already the following organisations have committed to RFID: Intel, Oracle, Microsoft, and SAP. This commitment is at the middleware level, which is a driver for change. This is a necessary condition for developers to embrace this technology, although it is not sufficient.

2.3 RFID Standards

The emergence of standards in any technological innovation is a tell-tale sign of market acceptance. This section examines the bodies that drive RFID standards.

2.3.1 Auto-ID Centre

In 1999 the Auto-ID Centre was formed at the Massachusetts Institute of Technology (MIT) in cooperation with numerous industrial sponsors for the development of RFID standards. This is widely credited as being the trigger for the elevated interest in RFID, particularly in the retail centre (Schmitt *et al.*, 2007).

The main output of the Auto-ID centre was the "Electronic Product Code" (EPC), a worldwide unambiguous numbering scheme for the designation of physical goods which should ensure the interoperability in supply chain wide applications (Sarma *et al.*, 2001).

The development of EPC provided a basis for a series of protocol standards for communications between transponders, scanner-hardware and information systems. The research centre closed in October 2003, and the functionality has now been commercialised and further developed by EPCglobal Inc, also a part of the organisation responsible for barcode standardisation. The research output of Auto-ID formed the technical foundation that led to Wal-Mart and Metro's adopting of RFID in 2006 (Sarma, 2005).

It is useful to point out that research emanating from the Auto-ID centre must necessarily be viewed as *a pro-RFID* centre with this bias in mind.

Since a key benefit of tags is the ability to be used throughout the supply chain much like barcodes, standards are mandatory for different vendors. This interoperability represents a key factor in determining the success of an RFID deployment and its commercial impact. There is already a huge concern that China is entering the market in a hurry and it may invent on an *ad hoc* basis. For example, if China does not adhere to the international unique number scheme there is a possibility of supply chain confusion with item values having different meanings (ABI Research Report, 2006).

Notwithstanding this concern, the two cooperating bodies that drive standards in RFID are ISO and EPCglobal. ISO is the overarching body for ICT standards in general, which includes even RFID. However, EPCglobal has a specific bias on RFID in the supply chain environment.

2.3.2 ISO

The International Standards Organisation (ISO) has developed standards that support selective read/write of data and common encoding rules for a number of air interface standards. The categories (RFID+ Certification Manual, 2006) are:

- Standards for communication between interrogator and tag;
- Data and systems protocol standards for RFID middleware;
- Identification standards for the coding of unique item identifiers or data residing on a tag;
- Testing, compliance, and health and safety standards that define the rules that govern RF transmissions with specific reference to RFID operations.

2.3.3 EPCglobal

Electronic Product Code global (EPCglobal) is a non-profit venture between various organisations involved in RFID (Niederman *et al.*, 2007). The aim of the EPCglobal network is to facilitate end-to-end visibility of goods and assets in an n-tier supply chain.

EPCglobal inherited all the intellectual property developed from the Auto-ID centre that was started at Massachusetts Institute of Technology (MIT) in 1999 to lead RFID research in retail supply chain (Niederman *et al.*, 2007).

Electronic Product Code (EPC) is a unique number that identifies a specific item in the supply chain. The EPC is stored on an RFID tag. EPCglobal is continually developing specifications to deal with data structures, RF protocols and methods of communication between the various components of the EPCglobal network (EPCglobal, 2008).

EPCglobal is also developing a universal electronic product code system and a global communication network to enable real-time and automatic identification of items in the supply chain (RFID+ Certification, 2006).

A relatively new concept called Global Data Synchronisation (GDS) has major retailers pushing their suppliers to become EPC compliant, that is, to publish and maintain their item catalogues at a global registry, enabling all parties in a supply chain link to exchange information about a specific product effectively. This is to pre-empt the "highly entrepreneurial and impatient" Chinese folk from creating their own numbering scheme.

The increased data accuracy enabled by GDS can save a lot of money for retailers and their suppliers. In fact, it is estimated that errors and misinformation currently cost these parties $40 billion annually (Jilovec, 2004).

2.4 Policy on Frequency Allocation

International restrictions apply to the frequencies that RFID can use. Therefore some of the previously discussed frequencies might not be valid worldwide. Each of the frequencies works for certain applications. If one wished to track people, then it is essential to know the legal operating frequency range in each country. Figure 2.5 graphically summarises these legal ranges. This figure shows also that the RFID transmission frequency is gaining widespread use. Put another way, countries will not legislate a frequency which is seldom used.

While there is unanimity in the LF and HF range, UHF uses different frequencies. Table 2.2 now summarises the legal frequency ranges for each band for some countries. It is worth noting that in South Africa no official frequency has been allocated to RF yet.

Table 2.2 International RFID Frequency Regulations and operating conditions (Lahiri, 2005)

Country/Region	LF – KHz	HF - MHz	UHF – MHz
United States	125-134	13.56	902-928
Europe			865-865.5
Japan			**Not allowed**
Singapore			923-925
China			**Not allowed**

Indeed the South African Government in a gazette (Gazette, 2006:2) acknowledges that "it has been inundated with spectrum allocation requests for RFID by different vendors". To this end the Independent Communication Authority of South Africa (ICASA) led the expression of interest on this matter. It states:

> *The endless innovative applications of RFID have the potential to contribute immensely to the national economy, advancing the competitiveness of the telecommunications industry as economic driver.*
>
> (Gazette, 2006:3)

However, the same document warns, RFID "must encourage innovative solutions without causing harmful interference to other services co-existing in the same spectrum." In 2006, the South African Gazette called for comment in preparation of developing legislation with regard to RFID and this call ended in November 2006 (Gazette, 2006:4).

Internationally, Canada has released a detailed position paper on RFID (Cavoukian, 2004). The European Commission launched a public commission on RFID in 2006 and called for public submissions on RFID. It is clear that policy is important as this informs intent, which in turn enables adoption.

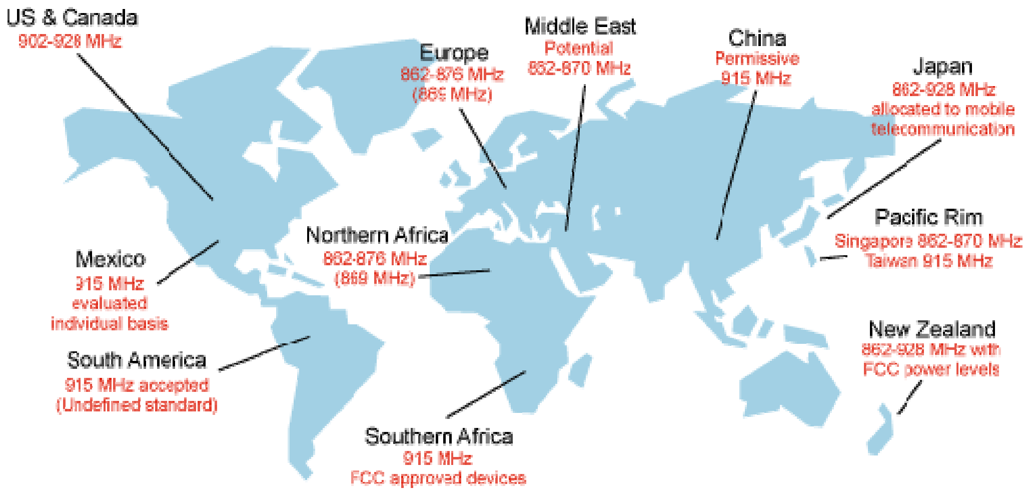


Figure 2.5 Using RFID for people tracking (IBM Developer Works, 2006)

2.5 RFID and Privacy

Privacy may be invaded or compromised by the ability to track items that people carry (Roberti, 2003). It is now possible, for example, to track Muslims by simply checking if they purchase or carry Halaal goods. Within a store, this may not be invasion of privacy but tracking them outside the store is. In fact, tracking a person's shopping habits in-store could even be a marketing opportunity when a store would display other items of interest to this shopper. However, "information about an individual belongs to that person, and is to be communicated or not, as the individual determines." This information communication privilege is called self-determination.

Losing control of one's personal information would mean losing control of one's life (Holmes, 1972).

The European Commission writes the following on RFID-enabled systems:

> *These networks and devices will link everyday objects into an "internet of things" that will greatly enhance economic prosperity and the quality of life. But as with any breakthrough, there is a possible downside – in this case, the implications of RFID for privacy. This is why we need to build a society-wide consensus on the future of RFID, and the need for credible safeguards. We must harness the technology and create the right opportunities for its use for the wider public good.*

(European Commission, 2006:1)

On the other hand, the American government under George Bush in the aftermath of the 9/11 terrorist attack announced plans for a Total Information Availability (TIA) that would allow American government agencies to gather information from disparate databases. From an RFID perspective, this TIA could know every transaction involving RFID that a particular person made! The Bush government said that the purpose was to gather intelligence to prevent future terror attacks: indeed *the pathway to hell is paved with good intentions.* Others label this the *era of big brother* especially with the advent of laws in the USA like the "Patriot Act II", where authorities have the power and provisions for profiling based on the tracking of purchases. RFID makes it easy to invade privacy. It may ultimately even allow for cradle-to-grave tracking and surveillance (Kumar, 2004).

The Electronic Privacy Information Centre (EPIC) recognising the impact that RFID will have on Security and Privacy issues has released a policy paper on RFID. This paper concluded that privacy and civil liberties could be threatened in the following ways (RFID Position paper, 2006):

a. **Hidden placement of tags.** RF devices can be secretly embedded on objects without detection. Such objects can be tracked through plastic, shopping bags, suitcases, and more.
b. **Unique identifier for all objects.** Such objects can now create a correspondence between the holders of the object at every point.
c. **Massive data aggregation.** RFID can result in massive databases containing unique tag data. If this were linked to TIA, government would know almost as much about ourselves as we do.
d. **Hidden readers and individual tracking.** As tags can be read from a distance, it is now possible with appropriately placed readers to track customer surreptitiously. A big brother syndrome could, for example, emerge if an agency can track individuals at a political rally with particular tee-shirts.

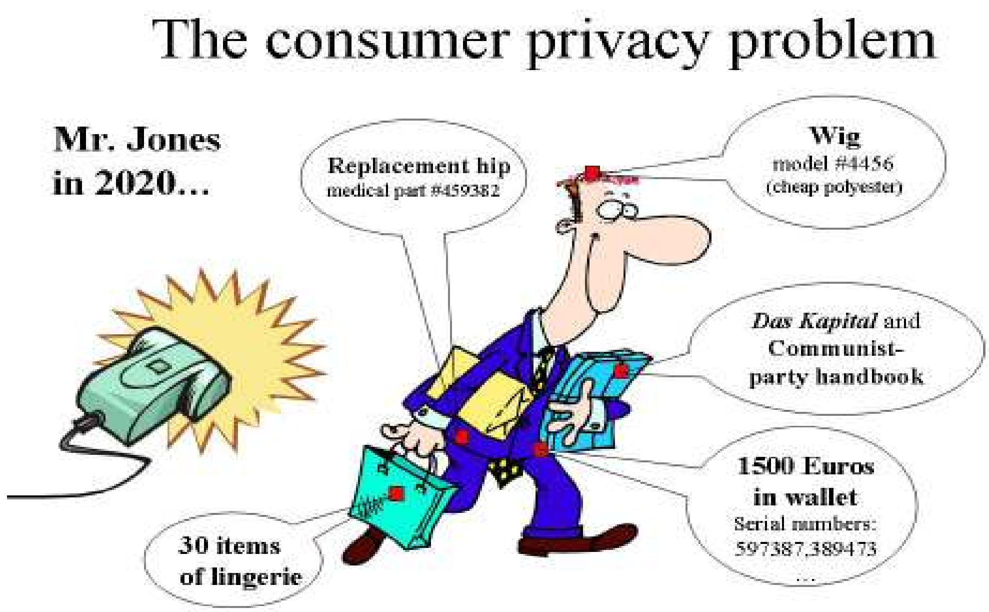


Figure 2.6 An illustration of potential consumer privacy of RFID (Juels, 2005)

The threat of invasion of consumer privacy is comically illustrated by Juels (2005). Yet this is serious business. The prospect of tracking someone through a product they buy or unwittingly carry on them is illegal as it is an invasion of privacy (Juels, 2005). It is this fear of ubiquitous tracking (monitoring) of a person by using an appropriate reader *without* that person's knowledge or consent that prompted many individuals and privacy advocacy organisations to voice strong opposition to the widespread implementation of RFID tags (Cavoukian, 2004:15).

Views on privacy are divergent in industry. A South African senior manager was equivocal: "We will wait and see. In the absence of a dominant view on privacy we will wait for one to prevail and then decide." In South Africa, for example, the Airport Company of South Africa which runs all airports has decided to wait for guidance from the Constitutional Court before implementing a system that tracks baggage using RFID (Personal Communication, 2007).

2.6 RFID and Security

As RFID is a wireless transmission, it becomes theoretically possible to intercept or eavesdrop on a tag and reader communication. It is for this reason that all RFID communications are encrypted. This level of encryption is gaining in sophistication, but as with any encryption, decryption is mathematically possible.

Tanenbaum *et al.* (2006) showed that it was possible to hack into an RFID chip and install a computer virus. Even the title of the paper was scary: "My cat is infected with a (computer) virus." Experts pointed out that this could only happen under very specific circumstances, all of which are rare, unlikely and contrived.

The difference between barcodes and RFID is illustrated by the following: A barcode on an item identifies the type or genre of that item. It could say, "I am a 25 g packet of Lays hips", which the computer software determines to be a particular price which the customer pays. This read result would pretty much be the same in Johannesburg as in London but it says little about the product itself.

An RFID tag on the same item could say, "I am a 25 g packet of Lays chips made in Durban using Potatoes from Farmer Obed, Oil from Sunfoil, and I was fried on 25/6/2008 in batch number 204 and delivered to Checkers on 24/7/2008 and I am best before 25/12/2010." This read is time and location independent; thus if this were bought in London, it would reveal this same result. In the modern era, the risk of industrial sabotage and terrorism is high so knowing where a product emanated from is very useful (Thakur, 2007:b).

Barcode itself took thirty years to get universal acceptance. In South Africa customer resistance to barcode was addressed with a marketing campaign that promised that if the retailer scanned a barcode incorrectly, then the customer would get the refund in full (Personnel Communication, 2007). It is useful to note that one store in the Philippines uses RFID entirely in its store.

As the Commissioner expressed:

> *RFID tags are far cleverer than traditional barcodes. They are the precursors of a world in which billions of networked objects and sensors will report their location, identity, and history.*
>
> (European Commission, 2006:4)

Some view "RFID as barcode on steroids", others call RFID a "barcode replacement technology". A third, more mature view is that barcodes and RFID can co-exist, with RFID offering features that will enhance tracking-and-tracing. Both barcode and RFID belong to a class of technologies called Auto-ID. Barcode was standardised in 1970 and is by far the largest Auto-ID technology. RFID is unlikely to realise this top position although RFID offers many advantages over barcode and even works in some environments in which barcodes cannot (Pohoresky, 2003).

Barcodes have been estimated to make a hard saving of 2.76% on expenditure and a soft saving of 2.89% on inventory control. The industry estimates that the cost reduction adds up to more than $17 billion in total annual savings taken from every area of its end-to-end value chain, starting from production and ending on the store shelf. This is due to the efficiencies that barcode adds in tracing and tracking inventory in a paperless manner (Haberman, 2001).

It is interesting to note that in spite of these advantages, barcodes took thirty years to become ubiquitous, far exceeding initial expectations. This may be explained by the fact that chain stores were not being as automated as they are now. RFID will not experience such technology barriers due to the prevalence of ICT infrastructure in most organisations. It is estimated that over five billion barcodes are scanned each day in 140 countries (Agarwal, 2001).

Barcode technologies use laser or optical light as the data carrier. In contrast, smart labels and RFID in general use radio waves to carry data. Barcode is therefore referred to as an optical technology and RFID is called a radio frequency or RF technology. Table 2.3 is a comparison of RFID with barcodes.

Table 2.3 A Comparison of RFID and barcode (Jilovec, 2004; Finkenzeller, 2003; Pohoresky, 2003; Lahiri, 2005; Daniel Hunt *et al.*, 2007)

Comparison Criteria	**Barcode**	**RFID**
Human-readable	Yes	Partial, as portions may be human-readable
Line-of-sight requirement	Yes	No
Read/Write	Yes	Read-only

Comparison Criteria	Barcode	RFID
Read one label at a time	Yes	Read multiple tags simultaneously
Standards defined	Yes	Standards being defined
Human interaction needed	Yes	No- automated reading with minimal human interaction
Reasonable read rates	Yes	Improved read rates
Not conducive to all environments	Yes	Can withstand a wide range of environments
Very low interference	Yes	Metals and noise interference
Specific content	Yes	Dynamic content
Inexpensive labels	Yes	Expensive tags
Mature technology	Yes	Evolving technology
No social issues	Yes	Several social issues
Mature technology with large installed base	Yes	Mature industry with few applications and a small base
Absence of international restrictions	Yes	No

Table 2.3 shows that both barcode and RFID technologies have their own advantages and disadvantages. On the one hand, barcodes are now pervasive and mature with well defined standards, with very low interference, inexpensive labels, and with no social issues. On the other hand, RFID does not require line-of-sight, and it can read multiple tasks with dynamic content.

2.7 Conclusion

One would imagine that RFID at 65 years old would be facing retirement as a technology, yet it has not even come of age with respect to mainstream adoption. Its adoption has been steady although discussions around it far exceed its use. Many younger technologies with an arguably lesser impact on business have already become entrenched in the market, for example, barcodes.

This chapter has introduced the protocols behind RFID. It examined the elements of the RFID ecosystem such as tag type and features, operating frequencies, standards policies and the issues they may present. It discusses the important bodies and organisations in RFID such as Auto-ID centre, ISO, EPCglobal and the role they play. **Chapter Four** discusses the frequency in some detail so that RFID transmission may be contextualised. RFID and barcode are also discussed in some detail because of their perceived impact on business. It ends by reflecting that RFID should have been used by now given its relative age.

The next chapter introduces the existing theory on adoption or diffusion of innovations so that one may study the perceived adoption of RFID, or lack thereof.

Chapter Three
Diffusion of Innovations

3.1 Introduction

This chapter is a review of the theoretical framework on the diffusion and adoption of technology. As pointed out by Rogers (1995), "No other field of behaviour science research represents more effort by more scholars in more disciplines in more nations" than the field of the diffusion of innovations. It is prudent to point out that the words "adoption" and "diffusion" are used interchangeably by both researchers and ICT practitioners.

This chapter examines significant relevant theories such as technology adoption lifecycle theories, innovation or diffusion theories, and the attributes of innovation. The attempt to study RFID adoption in this framework is in line with Surry (1997) according to whom Rogers' "effort is the closest any researcher has come to presenting a unified theory of diffusion".

3.2 Technologies adoption examples

As the researcher grew up as a young adult working with in ICT in the 80's he was fascinated by the proliferation of XT's, AT's, and 386's microcomputers. As an individual who had both a Mac Plus and an IBM PC XT, he was fascinated to find out which PC system would dominate. At that time logic postulated that the Mac would "win", given the initial USA impetus. But history informs us otherwise. The result is that the researcher is typing this thesis in Windows! Perhaps the truth is that arguably both the Mac Plus and the IBM PC XT were successful, just that the magnitude scale of success was different.

The adoption of Enterprise Resource Planning (ERP) is another area of fascination because of the risks of vendor lock-in, and the magnitude and disruptive nature of ERP projects. There is no evidence in literature of a single governmental, city or municipal ERP system that was adopted in time and within budget, this in spite of the pedigree of the consultants involved (Light and Papazafeiropoulou, 2004). Indeed, it is crucial to understand that the adoption decision is also a *calculated risk* as Russell and Hoag (2004) remind us of the perils of ERP implementation: one of the dramatic failures in ERP rollouts led to the near collapse of an ERP adopter named Department 56's. They then filed a lawsuit against the then implementer Arthur Anderson (Russell and Hoag, 2004).

The rapid adoption of the Internet is another interesting example of technology diffusion as Microsoft bet against it happening. Microsoft Chairman William Gates in his tearful farewell speech at Microsoft (Gates, 2008) candidly admitted as much. So, even *the* guru of commercial ICT got the diffusion of arguably the greatest event of his own lifetime wrong when he labeled the Internet a passing fad and unimportant (Gates, 1995).

In recent times with ICT, the following technology diffusions are of interest: broadband, cellular phones, open source and now of course RFID.

The above discussion demonstrates that diffusion requires more thought and analysis. Therefore there is a need to place technology adoption within a sound theoretical framework. Some basic theory is now introduced.

3.3 Basic theory of diffusion

According to Rogers (1995) an **innovation** is an idea, a practice, or an object that is perceived as new by an individual or by another unit of adoption. It matters little whether the idea is "objectively" new as measured by the lapse of time since its first use or discovery. The perceived newness of the idea for the individual determines his or her reaction to it. If the idea seems new to the individual, then it is an innovation. The **rate of adoption** is the relative speed with which an innovation is adopted by members of a social system. **Diffusion** is a process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication in that the messages are concerned with new ideas. The process of diffusion is considered to evolve around four key elements: an idea or innovation; channels of communication to spread knowledge of the innovation; time during which diffusion takes place; and a social system of potential adopters in which this occurs (Rogers, 1995).

A broad theory called **Diffusion of Innovations (DOI)** describes the patterns of adoption, explains the mechanism of adoption, and assists in predicting whether and how a new invention or innovation will be successful.

The **Diffusion of Innovations** theory was proposed by Rogers in his widely cited *Diffusion of Innovations* books, the first edition of which appeared in 1962, which studied and classified 405 diffusion cases. The second edition published in 1971 classified 1 500 diffusion cases. The third edition was published in 1983 and it classified 3 085 cases. And the fourth and fifth editions respectively published in 1995 and 2004 classified 4 000 and 5 200 diffusion cases respectively (Rogers, 2003). The first three editions have been cited 2 145 times (Rogers, 1991). Rogers' work has been extensively cited by researchers in the field of technology diffusion and diffusion of innovations theory has enjoyed a spectacular rise in academic research. In fact the *Diffusion of Innovations* book today is the second most cited book in the social sciences. This is why Rogers is used as a basis to try to understand RFID.

Rogers is of the opinion that each adopter's willingness and ability to adopt an innovation would depend on their respective awareness, interest, evaluation, and trial. He consequently classified adopters into different categories: innovators, early adopters, early majority, late majority and laggards. As Rogers (2003) explains, a farmer may be an early adopter of hybrid corn, but a late majority adopter of a VCR.

There are many perceived attributes of innovation that influence technology diffusion. For example, cellular phones diffused in a just a few years but the usage of seat belts in cars did not. Rogers indentified the following main attributes of innovation: relative advantage, compatibility, complexity, trialability, and observability. These attributes are discussed later in this chapter. The full diffusion of innovations theory is so rich and complex that no one study has ever tested every attribute. The common strategy is to choose a selection of hypothesised relationships among variables in order to determine which variable influenced the adoption decision (Russell and Hoag, 2004). Indeed, even with extensive writings on adoption and the diffusion of innovations, the adoption of new and emerging technologies with unique characteristics is still not well understood (Sharma *et al*., 2007).

There are numerous theories and models on technology and adoption. But three have been identified as a theoretical foundation for technology adoption namely Rogers' Innovation Diffusion Model (1995), Rogers' Technology Adoption Lifecycle (1983:271) and Moore's Adoption Lifecycle (1991). They have been chosen for the impressive structural synopsis that they offer in describing the evolution of a market anchor around a new technology from birth to maturity.

3.3.1 Technology Adoption Lifecycle

The adoption of technical innovations depends on many factors. In society, one knows of individuals who will buy almost *any* new invention, and conversely one also knows of folk who will not adopt technology innovations "till hell freezes over."

The **technology adoption lifecycle** was a sociological model, originally developed to track the purchase patterns of hybrid seed corn by farmers but has since been broadened by Rogers (1962).

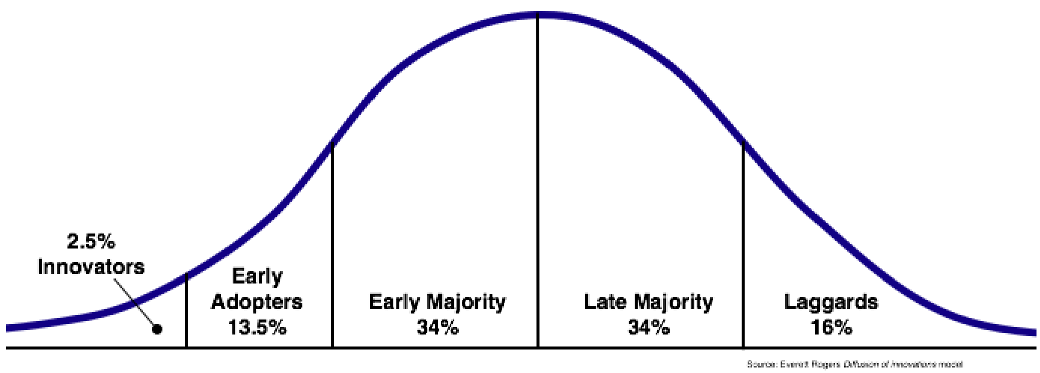


Figure 3.1 A graph of Rogers' technology adoption lifecycle model (Norman, 1998)

The process of adoption over time is typically illustrated as a classical normal distribution or "bell curve" as in Figure 3.1. The model indicates that the first group of people to use a new product are called "innovators" followed by "early adopters." Next come the early and late majority, and the last group to eventually adopt a product are called "laggards."

The innovation-diffusion model by Rogers (1983:271) considers the manner and rapidity with which an individual or other unit of adoption responds to the offer of an innovation. Rogers observed that the adoption rate distribution is almost similar to a normal distribution. He utilized the two statistics, mean (μ) and standard deviation (SD), to perform the adopter categorization. Figure 3.1 shows, that the area lying within the left third quartile is the first 2.5 percent of adopters. These individuals are referred to as *innovators*. Similarly, the other four categories of adopters were identified and referred to as *early adopters*, *early majority*, *late majority*, and *laggards*. Rogers also formulated the S-shaped curve, which represents the cumulative number of adopters.

A simpler view of Figure 3.1 is that 2.5 % of the population are innovators.

3.3.2 Bell and S-Curve

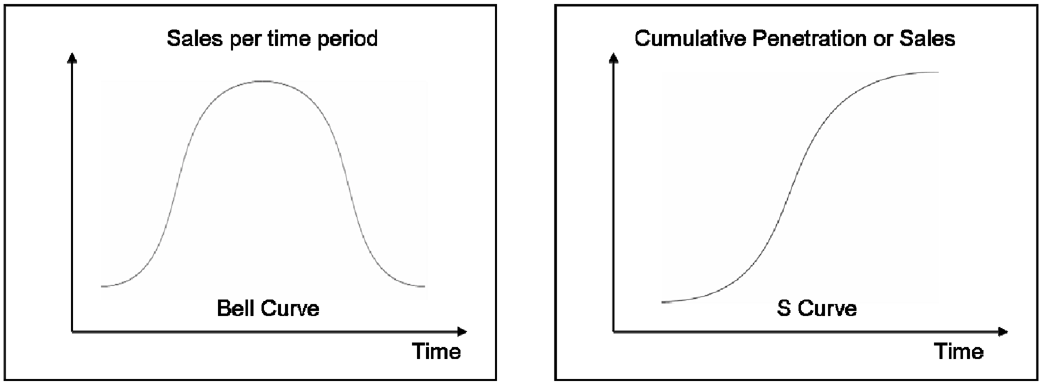


Figure 3.2 The Bell Curve and the S-Curve (Wynand, 2007)

Figure 3.2 shows the bell-shaped curve and the S-shaped curve for the penetration of technology sales. These two curves are related over time. In order to understand the two consider, for example, the sale of cellphones since the 1990's. Initial sales were low and it then had an explosive growth which will be seen in the S Curve. Now, in the noughties (2000's), although sales volumes are high the growth is low as the market reaches saturation. This implies that the market is currently near the top of the S curve.

The characteristics of the five categories of adopters as defined by Rogers (1983, 2003) and Moore (1991, 1999) are now described.

Table 3.1 Characteristics of adopter categories (Moore, 1999; Rogers, 2003)

Categories	Characteristics	Examples and notes
Innovators	• Eager to try new ideas • Embrace new technology • Cost is not an issue to them • Do not mind if leading edge turns to bleeding edge	Purchasers of the first VCR's, compact discs, camcords Current innovators: Voice Recognition systems Attempts at tracking whales (Rogers, 2003).

Categories	Characteristics	Examples and notes
Early adopters, also called visionaries	• Have the vision to adopt a new technology because of business opportunities • Cost is not an issue • Have the ability to match an emerging technology to a strategic opportunity • Do not need trackable or well established references to make choice	High profile people listed as visionaries are Steve Jobs, for taking Xerox PARC interface to the market as the Apple brand, and Henry T Ford for taking the automotive to people (Moore, 1991) Tend to communicate horizontally across industry boundaries in search of opportunity
Early majority, also called pragmatists	• Avoid risks by staying away from "bleeding-edge" technology • Quick to adopt technology that demonstrates benefits – "leading edge" technology • They are risk averse and do not equate risk with opportunity but a way of losing money	Buyers who stayed away from Windows OS until version 3.0 or 3.1 People who use EAS tags, e.g. small apparel retailers Pragmatists communicate vertically in their market, that is, they prefer to talk to peers in their own sector
Late majority, also called conservatives	• Do not adopt a new technology until the majority in their systems have done so • The weight of public opinion must definitely favour the innovation before the late majority is convinced	These are folk against discontinuous innovations There are as many pragmatists as there are conservatives
Laggards also called skeptics	• Last to adopt • Openly suspicious of innovations • When laggards finally adopt an innovation, it may already be superseded by a more recent idea that the innovators are using	People who now use barcodes They do not take part in high technology except to block its usage The resistance may be partly economic or partly personal

3.4 Diffusion of innovations and Size

Size is the most compelling concomitant to innovativeness (Rogers, 1995). Mahler and Rogers (1999) found that size was a dominant factor in a study of the innovativeness of 324 banks in Germany. Mahler and Rogers assert that big companies are more likely to adopt technologies. This is surprising given that conventional wisdom suggests that smaller organisations are more flexible and therefore more innovative in their operations.

In the case of the Mahler and Rogers study, the size of the organisation was measured in terms of its number of employers, its total assets, its number of branches or its number of customers, showing that the characteristic "size" varies.

3.5 Criticisms of Innovation Diffusion Theories

According to Rogers many DOI studies make simplifying assumptions as it is a complex field with many tangible and intangible variables. Rogers, himself made four observations criticising DOI theories:

a. **Pro-innovation bias of diffusion research**

   This is the implication of most diffusion research that an innovation should be diffused and adopted by all members of a system, that it should be diffused more rapidly and that the innovation should neither be re-invented nor rejected. This is because the act of innovation is heavily laden with a positive value. It should be acknowledged that rejection, discontinuance and re-invention frequently occur during the diffusion of innovations and that such behaviour may be rational, for example, is it a good idea for ERP systems to be adopted by *all* companies?

   This perceived bias may lead companies to ignore the study of innovation, to underemphasise the discontinuance of innovation, to overlook re-invention, and to fail to study anti-diffusion programmes designed to prevent the diffusion of bad innovations like marijuana, drugs or cigarettes (Rogers and Shoemaker, 1971).

b. **The individual blame bias in diffusion research**

   Rogers concedes that there is a pro-innovation bias in much diffusion research. More problematic, however, has been a source-bias, a tendency of diffusion research to side with the change agencies that promote the innovations rather than the potential adopters. In other words research sponsored by a state health department would, for example, be better received than one by a drug company.

c. **The recall problem in diffusion research**

By definition, innovation diffuses with time. A weakness is the dependence upon *recall data* by respondents on their date of adoption of an innovation. When one considers the study of cell phone adoption, would users remember the precise time, model and contract type, they got with their initial cell phones?

d. **The issue of equality in the diffusion of innovations**

Most Diffusion of innovations theories concentrated on DOI rather than on the consequences. These have more impact in social interventions where gaps widen between rich and poor. This study is desirable as RFID could introduce a competitive advantage to third world countries (Rogers, 1995).

3.6 Moore's Technology Adoption Lifecycle Model

Moore's Technology Adoption Lifecycle model (TALC) describes the adoption or acceptance (diffusion) of a new product or innovation, according to the demographic and psychological characteristics of defined adopter groups (Moore, 1991).

From Rogers' innovation diffusion model, it is evident that there are certain differences in the characteristics of adopters that influence them in their decision to try innovations at their chosen time. Moore's Technology Adoption Lifecycle (Moore 1991), which is derived from Rogers' model, clearly illustrates the evolution of a technology-enabled market.

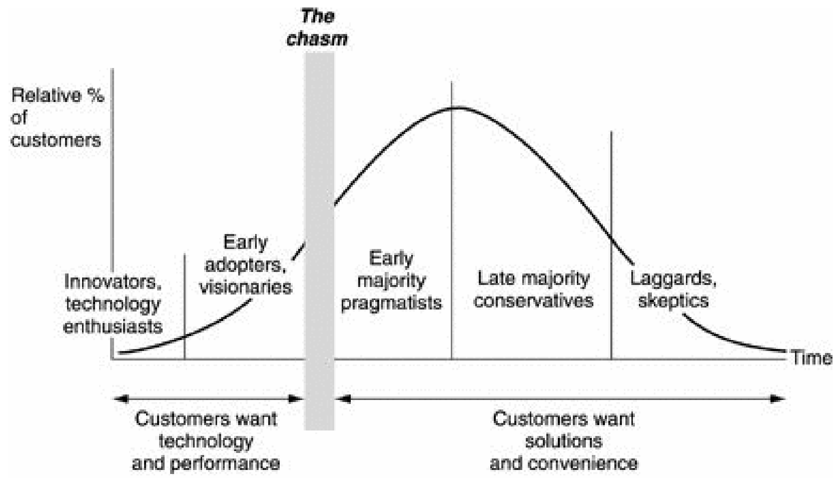


Figure 3.3 Moore's Bell shaped Technology Adoption Curve (Searls, 2003)

Figure 3.3 illustrates the change in customer's expectations as the technology matures. In the early days, the innovators and technology enthusiasts drive the market; they demand technology. In the later days, the pragmatists and conservatives dominate; they want solutions and convenience. One may note that although the innovators and early adopters drive the technology markets, they are really only a small percentage of the market; the big market is with the pragmatists and the conservatives (Moore, 1991).

Moore determined that the normal distribution curve was found to be too simplistic. He found its categories to be correct but he also found that there is a distinct **gap** between each group. This gap disassociates two adjacent gaps. This also represents a missed opportunity for market players to move to the next category.

The chasm is the gap between the early adopters and the early majority. The early adopter purchases an opportunity to edge ahead of the competition. They want to be first: to be faster, better, simpler as the case may be. For this, they are prepared to endure the bugs and glitches that accompany the innovation. An early adopter is a visionary. The early majority, however, wants productivity improvements with an innovation that works properly, and integrates with existing technology. Early majority wants evolution not revolution. A member of the early majority is a pragmatist.

Moore tried to understand Rogers' Adoption Curve so market players could influence adoption decision making in order to get over the chasm. More than that, he was interested in the psyche of the categories in the context of disruptive technologies. From the researcher's point of view, RFID is disruptive because it will certainly change the supply chain and how it operates.

3.7 Discussion on Moore, Rogers, Von Hippel and Norman

One may notice that organisations on the left side of the chasm are more interested in the potential of the idea and are willing to take a risk, whereas organisations on the right are very conservative and will wait for "solid proof" that the idea works in practice. Crossing the chasm means overcoming the challenge of promoting a technology with a defined market space.

Moore (1999) indeed argues that there is a "market chasm" between early adopters and the early majority. He believes that the needs of the early adopters are radically different from those of the pragmatic early majority that constitute the mass market. Moore has observed that many new products failed simply because they were not able to "cross the chasm", in terms of new product design and marketing strategy, when moving from the early market to the mass market.

This idea gained widespread usage in Silicon Valley after Moore released his seminal book on marketing technology products "Crossing the Chasm" (1991) which reintroduced and refined the Technology Adoption Lifecycle (TALC). It emphasized that the attitude of adopters becomes significant when introduced to products that require a behavioral change which is called *discontinuous innovations.* A current example would be HDTV (High Definition Television), which requires a complete change in broadcast standards, television sets and *all* antennas. By contrast *continuous innovations* refer to a normal upgrading of products and do not require much behavioral change. An example here would be Plasma Screens or LCD's replacing tube televisions (Moore, 1991; 1999).

Moore stated that the following are victims of the chasm: Gigabit Ethernet, cable modems and Digital Subscriber Loops (DSL), Voice Processing with diction and PDA's, IP telephony and Artificial Intelligence. One may note that the chasm is not necessarily the *death* of the product – it is just a point that prevents an innovation from moving upstream as a product in terms of adoption. The chasm, whatever its size, is the point that any marketer wants to cross as soon as possible (Moore, 1991; 1999).

Moore, however, asserted that the best way to market an innovation is on a market segment-by-segment (vertical or cluster) basis as this ensures marketing is aimed at the targeted audience.

From the researcher's own experience, an example of a ICT product that did not cross the chasm is CASE based reasoning tools. At a higher level in ICT, one may include the sub domains of fuzzy logic and neural networks as further examples.

3.7.1 Criticism of Moore's Model

The researcher contends that Moore was wrong in some of his analysis. Of course the researcher has the benefit of ten years of hindsight since Moore's book (1999). Moore, for example, postulated that DSL's and IP Telephony which we now call VOIP were chasm victims. This is understandable given the reference point of 1999 when the book was published. Indeed, Rogers himself (2003) was not convinced that the chasm existed at all. Yet, VOIP and DSL are now two significant "techno waves" in the world.

Out of seven examples suggested by Moore to have fallen into the chasm, five have gone on to become adopted technologies. This demonstrates the folly of trying to predict the adoption at too early a point along the adoption curve. The question is *where* this point is? Moore himself acknowledges the danger of predicting the crossing of the chasm as "a high-risk, low data decision" (Moore, 1991). Another conclusion that can be gleaned from Moore is misplaced prediction is that it graphically illustrates that an idea, before its time, may bid its time, like the fax machine. Also early success of a product does not determine success (adoption). It is a necessary but not sufficient condition.

A problem with adoption curves is that they only make sense *post facto*, that is, when a particular technology has passed its time. This study will, despite Rogers' reservations, attempt to establish if RFID is in the chasm or on either side of it. Less controversially, it will see if RFID is in the early majority stage.

3.7.2 Discussion of Rogers' and Moore's Adoption Curve Models

It must be pointed out that Moore's curve is a specific instance of Rogers' curve. Moores' theories are applicable for disruptive or discontinuous innovations. Adoptions of continuous innovations (that do not force a significant change of behaviour by the customer) are still best described by the original Technology Adoption Lifecycle.

Confusion between continuous and discontinuous innovation is a leading cause of failure for marketing “high tech” products.

Both Rogers’ and Moore’s models are based on the normal distribution and use the standard deviation for the categories identified in Figure 3.1 but Moore adds the chasm and the gaps. But Norman (1998) goes further by plotting and factoring in the chasm into the S-curve and the normal distribution. In the early days of a technology, buyers want more and more technology (See Figure 3.4). They will overlook instability, difficulty in use, and inelegant appearance. This is on the left hand of the chasm. At the later stages, the customer’s mindset changes radically. Now constomers want efficiency, pleasure, and convenience. This requires a very different form of product development than the one used in the early stages of a technology. This requires human-centred design on the right hand of the chasm.

Christensen (2004) finds that innovative, disruptive technologies are, at first, perceived as toys. At that point, except for innovators and early majority adopters, the market sees them as overpriced and underpowered. This market’s opinion at that point does not matter, as Christensen shows. In the end, though, these “toys” could dominate, killing those that went before, such as, hydraulic shovels, small disk drives and personal computers (Christensen, 2004).

Peng (2004) also notes that there is no available literature that provides an applicable method to identify the adoption stages of a new technology that has yet to reach the end of its lifecycle.

Figure 3.4 is a fascinating juxtaposition of the two curves. It indicates an emerging view that the vendor holds a strong case for enabling adoption in their customers.

3.7.3 Moore and Von Hippel

Both researchers, Moore (1991, 1999) and Von Hippel (2005), describe a bell curve. The x-axis is the same in both diagrams; it represents time. The y-axis, however, represents different things. For Moore, Norman and Rogers, the y-axis is the proportion of people who adopt an innovation in a given period of time (x-axis). For Von Hippel, the y-axis is the number of people who begin to experience the need for an innovation in a given period of time (x-axis).

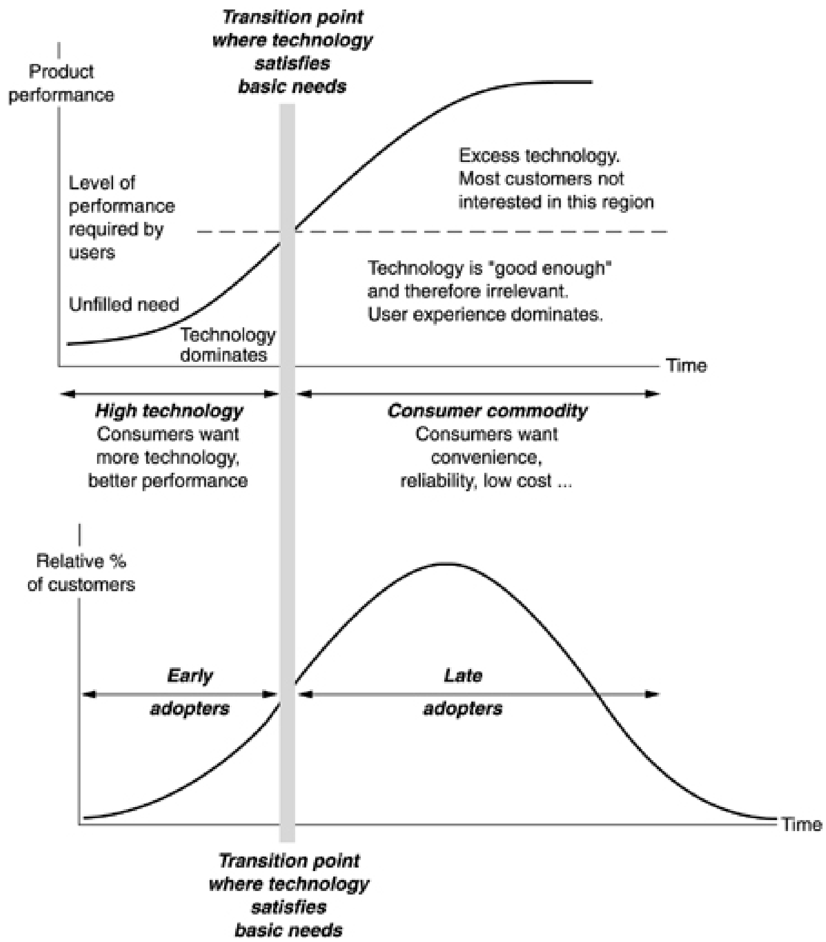


Figure 3.4 Dr Norman's Adaptation of Moore and Rogers (Norman, 1998b)

The curves are not necessarily correlated in time. If, for example, an innovation to address a need is never invented then Von Hippel's graph will show a bell-shaped curve where Moore's graph would show a flat line (y=0).

Conversely, in a particular span of time, Von Hippel's curve (Figure 3.5) may be flat while Moore's graph shows a bell-shaped curve if a solution appears suddenly on the market to a long-standing unaddressed need. Even when the trend towards an increasing need has already played out and everyone who wants a solution can obtain it, the diffusion will still be gradual and probably conform to a bell-shaped curve. This is because, as Moore argues, the mainstream of the market will refuse to adopt the solution until it is well proven by the early-adopters segment (Von Hippel, 2005).

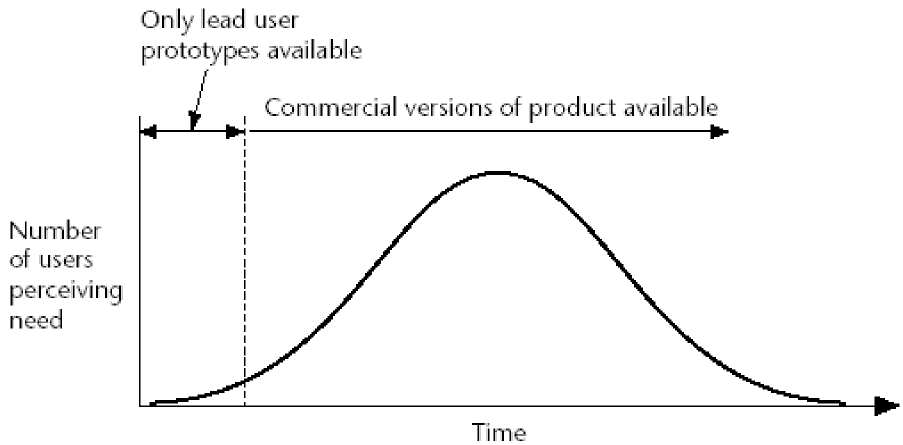


Figure 3.5 Eric Von Hippel's Lead User Bell Curve Diagram (2005)

3.8 Opinion Leaders and Diffusion of Innovations in Organisations

Existing DOI research shows that opinion leaders play an important role during the innovation process and they exert their influence via diffusion networks.

Rogers (1995) defines opinion leadership as "the degree to which an individual is able to informally influence other individuals' attitudes or behaviour in a desired way with relative frequency". One may recall that in the **innovation-decision process,** the individual passes from *knowledge* of an innovation to *persuasion, from persuasion* to *decision* to adopt or reject, and from *decision* to *implementation* in the case of an adoption decision, and then to an *assessment* or *confirmation* of this decision.

In the context of this study it will be useful to examine each of these factors for the research population in order to understand where we are in the innovation-decision process with respect to RFID. Put another way, we have to establish just how much knowledge (or hype) our opinion leaders have or generate about RFID technology.

3.8.1 The role of a champion

A champion is a charismatic individual who enthusiastically supports an innovation, overcoming any indifference or resistance that the new idea may provoke. The presence of a champion in an organisation may contribute to the success (or failure, if an opponent) of an innovation.

3.8.2 Diffusion networks

It was found that mass media plays a lesser role than opinion leaders in influencing people. Literature indeed shows that face-to-face contact with people is better than mass media communication. It appears that ideas flow from media to opinion leaders and from these to other sections of the population (Lazarsfeld and Menzel, 1963).

The heart of the diffusion process is the modelling and imitation by potential adopters of their near-peers who have previously adopted a new idea. But this process is usually enhanced by opinion leaders. A **communications network** consists of interconnected individuals who are linked by a patterned flow of information. This is problematic for analysis because mathematically there are $n(n-1)/2$ possible connections for a graph with n nodes. Hence, for a network graph of size 100 nodes, for example, 4 950 node-links are possible. **Communication Network Analysis** is a research method for identifying the communication structure in a system. Relational data about communication flows are analysed by using some type of interpersonal relationships as unit of analysis.

Mass media may be viewed as knowledge creators and communication networks likewise may be viewed as channels for persuading individuals to accept or reject an idea. These networks have a dimension called **communication proximity** which is defined as the degree to which two individuals in a network have the potential actually to communicate.

3.9 Innovation in organisations

This section focuses on organisations as distinct from individuals. An **organisation** is a stable system of individuals who work together to achieve a common goal through a hierarchy of ranks and division of labour. Organisations have goals, roles for labour, structures, rules and regulations.

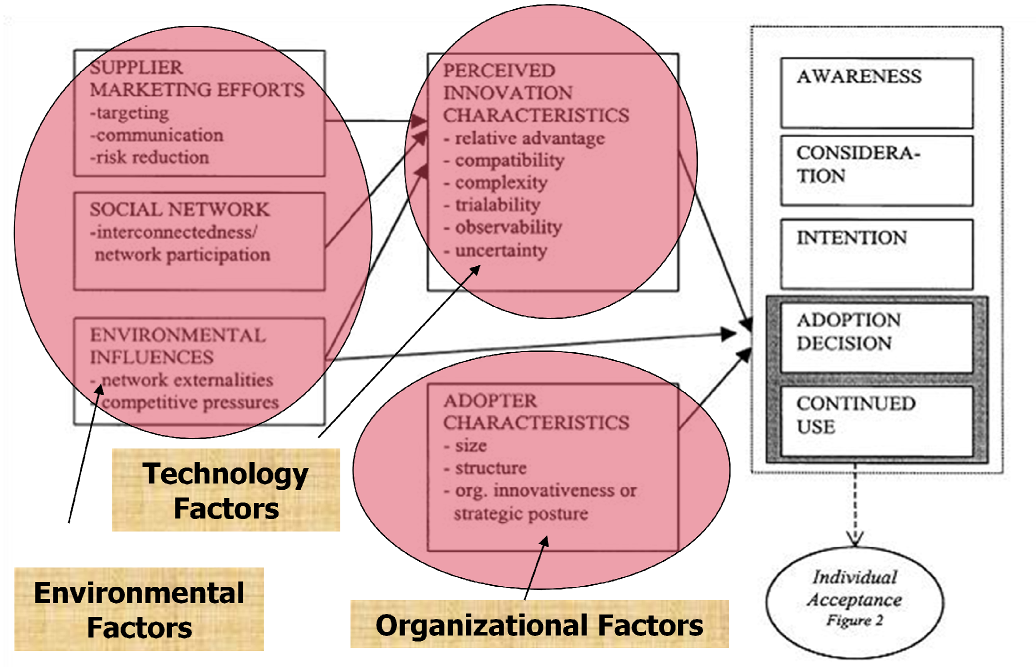


Figure 3.6 Innovation in organisations (Frambach and Schillewaert, 2002)

In organisations there are two types of innovation decisions: collective decisions versus authoritative decisions. According to Rogers (2003), most models that studied innovation focussed on the implementation stage of an innovation in an organisation. Yet this is just one stage of the diffusion process (Rogers, 2003). One may also note that once an organisation has made a decision to adopt, implementation does not necessarily follow. There is a distinct difference between organisational adoption and individual usage. For example, many companies purchase huge CRM systems but sales folk still use their own diaries, spreadsheets or contact systems.

Existing DOI research show that organisational diffusion is very complex but the variables shown in Figure 3.6 dominate (Frambach and Schillewaert, 2002).

In **collective innovation-decisions,** choices to adopt or reject are made by consensus among members in the system. Once a decision is made the result is binding to all in the organisation. For example, a referendum may be held on the death penalty and the referendum result will be adhered to by all judges regardless of their inclination. In **authority innovation-decisions,** the choice to adopt or reject an innovation is made by few individuals in a system that possesses power, social status or technical expertise.

3.9.1 Perceived attributes of an innovation

Rogers identified the following attributes of an innovation. The Frambach and Schillewaert model (2002) showed in Figure 3.6 draws from these attributes. Individuals perceptions of these attributes can help predict the rate of adoption.

a. **Relative Advantage** is the degree to which an innovation is perceived as being better than the idea that it supersedes according to economic profitability, prestige, etc. There are a number of dimensions to relative advantage, and they change over time. A product may be judged on the status it brings, because it is early on the market and it is expensive. However, lower costs as the product diffuses can completely change its relative advantage in terms of status, and in terms of its functionality as it becomes more accessible to the mass market. Some products have their relative advantage increased because of incentives offered by change agents, but this may not lead to long-term adoption. In some cases, there is a mandate to adopt, such as a law (e.g. Botswana legislating RFID in livestock).
b. **Compatibility** is the degree to which an innovation is perceived as being consistent with existing values, past experiences and needs of potential adopters. These include socio-cultural values, previously introduced ideas, and the needs of the adopters. Products are less likely to be successful if they carry meanings that conflict with basic values or established practices. This may point to a good reason to understand the stand of CASPIANS against RFID (Albrecht and McIntyre, 2005). However, if an innovation appears too similar to existing products people may not see the point in adopting it. This is why RFID must be shown to be different form barcode. This can also occur if an innovation is too similar to earlier failed innovations. Consumers are intelligent and experienced and can place innovations within a cluster of other technologies. They can draw relationships between technologies including relationships that were not recognised by experts from outside a local culture. An innovation also has to be seen to meet a need. However, this need may have to be constructed by a change agent in order to make the product salient.

c. **Complexity** is the degree to which something is perceived as being difficult to understand and use. This is negatively associated with adoption. Rogers gives the example of home computers. Earlier hobbyists did not see computers as complex (maybe they liked it that way). Later adopters of IBM PC were baffled by complexity and did not have technical expertise. Rogers, Daley and Wu (1980) found that users had 6-9 weeks of extreme frustration and, as a result, they had to join a computer club where they could obtain help from friends or others. Rogers *et al*. (1980) further suggest that the complexity of the PC was the reason for its non-adoption in the early 1980s.

d. **Trialability** allows things to be tried out before possible adoption. The trial allows the potential user to create a meaning from first-hand experience, thereby dispelling uncertainty. A positive trial usually results in adoption. Early adopters find trialability to be more important than late adopters as late adopters have lots of people around them who have already adopted. In this case, late adopter peers act as vicarious testers. This means that the late adopters often move to full adoption faster than innovators and early adopters.

e. **Observability** is the degree to which the results of innovation are visible to others. For example, Rogers (2004) suggests that software is less observable than hardware, so software diffuses more slowly. But the Internet has changed this. Technologies that are highly visible in everyday life are more likely to be adopted, since it is hard not to notice them and to learn something about what they are and how they are used. Of course at certain stages in the diffusion of a product, observability can have a negative influence if the technology or the users are seen as a social nuisance, or represent a group that someone is in opposition to (Rogers, 1995).

3.10 Conclusion

To gain an idea of the complexity of the study of innovations in organisations, Rogers refers to a large well-funded research program at University of Minnesota (Van de Ven *et al.*, 1989) studying just fourteen in-depth case studies of technological innovation that needed thirty scholars!

This chapter has presented Rogers' and Moore's theory on diffusion of innovations and the subsequent evolution on this by Norman and Von Hippel. It has also explained how champions interact in diffusion networks in order to influence the adoption process.

The final section of the chapter explains the five attributes of innovation: Relative Advantage, Compatibility, Complexity, Trialability and Observability as indentified by Rogers.

It is useful to quote Schrage (2004): “Innovation isn’t about crafting brilliant ideas that change minds; it’s about the distribution of usable artefacts that change behaviour. Innovators - their optimistic arrogance notwithstanding - don’t change the world; the users of their innovations do.”

The next chapter examines literature on the diffusion of innovations *and* RFID. It shows how fellow researchers have approached this topic from different perspectives within areas such as supply chain management, retail, logistics, libraries, automotive sector, sporting events, apparel, policy, regulation, privacy, security and geographic country.

Chapter Four

RFID and Diffusion of Innovations

4.1 Introduction

This chapter conducts a literature review of theses, academic papers and journals, where RFID *and* theories of diffusion of innovations or adoption is analysed. The chapter commences by providing an overall scan of the literature by bibliometric means. It then examines RFID in the different business verticals.

4.2 Bibliometric Analysis of RFID Research

Chao *et al.* (2006) uses the bibliometric technique, which utilises a statistical analysis of the patterns of publications. The bibliometric analytical technique was therefore used to examine RFID in the Science Citation Index (SCI) of journals from 1991 until November 2005. The year 1991 was selected by Chao *et al.* (2006) because there was very little data before this year.

Chao *et al.* (2006) examine various detailed searches for example when the keyword RFID is used in a title, or abstract, or when the keyword RFID is used in parameters such as authorship, patterns of international collaboration, journal, language, document type, research address, and the number of times a particular paper was cited.

RFID Citation Analysis was based primarily on the impact factor as defined by the *Journal Citation Reports* (JCR) and on *Citations per Publications* (CPP), which are used to assess the impact of a journal relative to the entire field and is defined as the ratio of the number of citations the publication has received to the length of time since publication (Chao *et al.,* 2006). Chao *et al.* determined that the total number of papers associated with RFID was 316 in 1991. Figure 4.1 is a graph that depicts this relative frequency.

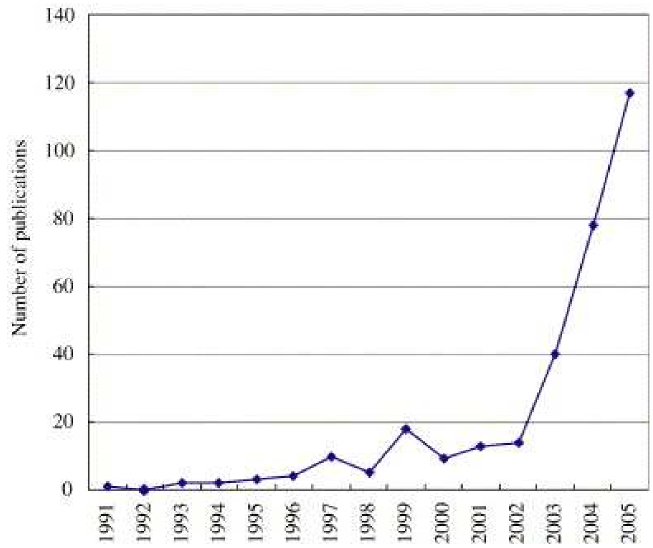


Figure 4.1 Annual publication output (Total publications: 316) (Chao, 2006)

The graph in Figure 4.1 presents technology trends and forecasts on RFID by a historical review from 1991 to 2005 and bibliometric analysis (Chao *et al*., 2006).

This study confirms that while RFID publications are on the rise, it is still a niche area of opportunity for research. The graphics validates this assertion. The next section considers RFID in different arenas.

4.3 RFID and verticals

The RFID papers reviewed by this study have evolved to become specific, that is, they have progressed from generic supply chain papers to vertical specific papers and from literature review papers to case study and questionnaire responses. In other words, the level of granulation is increasing.

Curtin *et al*. (2007) propose the most comprehensive research agenda in the domains of adoption, usage and impact of RFID respectively. This paper is worthy reading for any researcher interested in RFID technology and a research agenda for the study of the adoption, usage and impact of RFID in business in general. The paper coherently acknowledges all issues around RFID such as privacy and security (and the perceptions), usages, technology barriers, opportunities, and adoption in an organisational context. It identifies all players in the RFID market - the drivers, the obstacles to the drivers, etc. The paper is a non-trivial effort that has already attracted much attention as it climbs the citation ranks. As this paper is a *research agenda* it proposes research opportunities not solutions.

4.3.1 RFID, Supply Chain and Distribution Centre Operations

Pohoresky (2003) started the earliest study relating RFID to the Diffusion of innovations. He rightly boasts: "This is the first and only study to date to the best of my knowledge that has been conducted applying the five perceived attributes of innovation to RFID technology in a supply chain distribution centre environment." The review of the relevant literature supports this assertion. He dives right into the heart of Rogers' theory and asks the following questions:

> **RQ1:** What are the perceived attributes of innovation that facilitate or impede the rate of adoption of RFID? The attributes here are relative advantage, compatibility, complexity, trialability, and observability. These attributes were derived from Rogers' Theory of the Diffusion of innovations (Rogers, 1995).
> **RQ2:** How will RFID affect distribution centre operations?
>
> (Pohoresky, 2003:2)

Tables 4.1 and 4.2 select specific variables relevant to this research which also answer the research questions RQ1 and RQ2 that Pohoresky poses.

Table 4.1 Summary of RFID attributes & its effect on rate of adoption (Pohoresky, 2003:56)

Perceived Attribute of Innovation	RFID Attribute	Effect on Adoption Rate
Relative Advantage	No line of sight required	+
	Increased read range from barcodes	+
	Unique identity for each unit	+
	Greater capacity of information	+
	Durability against hazards	+
	Accurate readings	+
	Theft or counterfeit protection	+
	Proven results with Automatic ID	+
	Cost of tag	-
	Cost of reader	-

Perceived Attribute of Innovation	RFID Attribute	Effect on Adoption Rate
	Cost of Infrastructure (database storage, software, implementation, integration, consulting services, change management)	-
	Status perceived by others	+
Compatibility	Frequency, tag, reader standards	-
	International compatibility	-
	Change management	-
	Privacy concerns at item level tagging	-
Complexity	Reader collision	-
	Read range limitations	-
	ERP and software integration	-
Trialability	Pilot capability	+
Observability	ROI measurement capability	+

In Column 3 of Table 4.1 the + implies "facilitate" whereas the - implies "impede".

It is noted that this table is larger in Pohoresky's published thesis because there are more RFID attributes there. This researcher includes attributes only relevant to this study.

Pohoresky (2003) focused on RFID in Supply Chain Management (SCM) in distribution centres by extending the theory of diffusion of innovations. The nature of the study was exploratory since RFID applications as a novel phenomenon which has yet to be adopted by mainstream distribution centres. Pohoresky's thesis attempts to combine exploratory research of RFID analytically with the attributes of innovation proposed by Rogers in order to explain the rate of adoption. Various methods for acquiring research data were applied throughout the study. White papers, reports, case studies, periodicals, actual industry experience and interviews were used to obtain and analyse data. Pohoresky (2003) uses Rogers' generalisations to examine the impact of the generalisations.

Pohoresky's analysis was both bold and brave as this happened in 2002 when there was a lot of hype about RFID but available RFID products few and far between. An entirely forgivable flaw of this study is the lack of a case study or sample to test conclusions or suggestions. He was confident that RFID adoption would be widely evident in the near future, which is still not the case. He notes that RFID has become a waiting game as the market waits to explode. He does recommend that companies conduct pilots in preparation for the much expected launch.

Pohoresky RQ2: How will RFID affect distribution centre operations?

Table 4.2 Summary of distribution centre pain points & RFID remedies (Pohoresky, 2003:68)

Distribution Centre Pain Point	RFID Remedy
Receiving	
Delivered goods must be physically opened and checked	Automated confirmation of goods received
Line of sight required to scan barcode	No line of sight required
Individually scan each barcode	Bulk scan
Manually scan each barcode	Automated data capture with RFID reader at dock doors
Goods sent to wrong destination	Immediately flagged and reassigned
Mixed loads and multiple product pallets	Automated verification
Human error	Reduced human intervention
Proof of delivery task	Automated proof of delivery
Contract verification	Tag contains contract information
High level of order discrepancies	Reduced order discrepancies
Disgruntled supply chain relationships	Improved supply chain relationships
Cross Docking	
Limited cross docking due to lack of visibility in yard management and slow reception	Increased information visibility and faster reception enabling cross docking strategy
Putaway	
Print and apply new barcode	Automated information update of RFID tag
Inefficient use of physical holding space	Improved putaway strategies with locating capabilities
Picking	
Find and scan appropriate barcode	Automated location retrieval and data capture
Confirm pick details	Automated confirmation
Print and apply new barcode	Automated information update of RFID tag
Inventory	
Inaccurate inventory reports	Inventory movement visibility
Inventory audits	Automated inventory audits
Stock outs	Reduced stock outs from increased visibility
Shipping	
Cases scanned and checked against order	Automated scan with RFID reader at dock doors
Print and apply new barcode	Automated information update of RFID tag
Unfit goods sent	Automated information specific verification
Theft	
Stolen goods	RFID security monitoring
Recovery of stolen goods	RFID identification
Fraudulent returns	RFID identification

Pohoresky's Table 4.2 identified potential problems in a distribution centre which he labeled "pain points". He then determined appropriate remedies for these problems.

It would be useful for the reader to re-consider Table 4.2 with Lee *et al'* perspective (2007) by reading their contribution to RFID research in Section 4.3.4.

4.3.2 RFID and construction site logistics

Mortensen and Pedersen (2004) undertook a thesis on the study of the "Possible Use of RFID Technology in the Support of Construction Logistics".

A construction logistics site mimics a very dynamic process with many phases, many critical paths and a high demand for Just-in-Time (JIT) delivery methods. It may even need some just-in-case strategies to cater for emergencies. It involves multiple contractors with multiple supply chains. It also has a whole slew of construction equipment – some equipment that may leave and re-enter the site, some that can leave the site under certain conditions, and some that may not leave under any circumstances. The authors conclude that all of the above requirements spell a ripe application for RFID (Mortensen and Pedersen, 2004).

Even though the process of building a new structure is quite linear, a building site goes through many phases during the construction. During planning it is necessary to enumerate the critical paths and different building phases as this will influence the order in which deliveries are made.

Mortensen and Pedersen (2004) envisage a construction site where a central computer system "knows" the location of the materials at any time, and logs if such materials are moved. They worked towards building such a prototype.

They conducted an extensive literature review culminating with a study of a large scale housing project in Sophiehaven in 1994. The Sophiehaven research project had the active participation of the largest companies in Denmark as they cooperated to improve logistics in construction sites. This research project was then replicated at the Arendal Cultural Centre by the researchers in the form of a situational analysis and field study. They conducted interviews with the site engineer and procurement manager. In particular, they studied the procurement and logistics with regard to the supply and availability of doors and windows and how RFID can improve the supply chain for these typical building items. In Norway, this could be complex as there are over 350 000 products involved in construction from over 470 information sources. A prototype was then built and tested.

The Sophiehaven project determined that there were nine supply problems or errors in construction logistics and that some of these are inter-related. A simple count of the errors that occur most frequently are the following: insufficient work planning; insufficient delivery planning; bulk purchase discounts; project errors and other human errors. About 30% of these problems could be ascribed to the contractors, 15-20% to the suppliers and 10-15% to the project administration. The rest was ascribed to others, among these the transportation companies.

Mortensen and Pedersen (2004) reasoned that by using RFID logistics, the "process of making sure that labour and materials are at the right place at the right time" may be achieved.

Doors and windows are often custom-made for each project, which means that there is seldom appropriate stock to draw from. The delivery time is about eight weeks. Once on the construction site, the doors and windows are received by the contractors in charge of installing them. Errors in delivery are often not discovered until they are about to be installed, at which time the item may have to be shipped back to the manufacturer, possibly causing major delays. This was an area that RFID could assist in.

A theoretical framework was conceptualised and the development of a functional RFID prototype started. However, their industry mentor was reassigned and they had to stop this project. Instead, they did a review of available RFID software and hardware and tested their prototype in the logistics field. The prototype was able to read the tags and send them to a server over the GSM network, where it could be processed and the materials checked in. This prototype unveiled a serious problem with handheld RFID scanners: the scanning distance is too short to use on a construction site due to limitations of the battery. After a thorough analysis of its possible uses in construction, they concluded that "RFID is too immature to deploy in the construction industry today." This study also revealed that "gaps for RFID were at the middleware level - which was expensive both in purchase and support".

Mortensen and Pedersen (2004) displayed an element of prophecy as the reading ability of RFID scanners has since improved. Now the US Department of Defence uses RFID in its construction and logistics projects which has met with good success resulting in deployment in Iraq (Roberti, 2005c).

4.3.3 RFID and Retail

RFID has already been adopted by some large retail giants like Wal-Mart, and even led to the Future Store Initiative which is a group formed by SAP, Intel, IBM and Metro, the world's fifth largest retailer (Niederman *et al.*, 2007). This section focuses on the development of new processes in inventory management using technology such as RFID.

RFID and Wal-Mart

The Wal-Mart case study is mandatory as Wal-Mart's RFID adoption is the single biggest event in the history of RFID.

Hardgraves *et al.* conducted a comprehensive study (2006) of Wal-Mart's RFID rollout and its perceived impact on out-of-stocks. An out-of-stock is an empty shelf at a store forecourt because the product is still in the back room or has not been received yet. Out-of-stocks usually result in lost sales to the retailer.

With RFID, stores know what product have been delivered to the store, taken to the sales floor, or stored in the backroom. When this is combined with point-of-sale data, a much more accurate view of inventory, both on the shelf or in the backroom, can be provided.

The study lasted six months and gathered data from twelve RFID stores randomly chosen from 104 RFID enabled stores. The twelve control stores were chosen from a single geographical area. In all, 4 554 items were tagged from February 2005 to September 2005. The *sales velocity* was used. Sales velocity is a variable to determine the out-of-stock rate on sales and its impact on RFID. In other words, how many times was a sale lost due to unavailability of the item? The study determined that where between 0.1 and 15 items were sold at a store per day, the use of RFID reduced out-of-stocks by 30 percent. For slow moving items that sold less than one item every ten days (0.1 per day), RFID made no impact. For items selling between 7-15 units per day RFID reduced out-of-stocks by 62%.

These results are positive and encouraging and point to a robust indication of RFID's ability to reduce out-of-stocks. Hardgrave *et al.* (2006) coin and use the term "win-win-win" to describe the use of RFID for out-of-stock for the retailer, the supplier and the consumer.

Retail in South Africa

Brown and Russell (2007) conducted the most detailed study of RFID on the South African Retail Sector. They examined relative advantage, compatibility, complexity, and cost which are considered important to adoption of RFID technology. Each of these attributes is formulated by Brown and Russell (2007) into an appropriate proposition. Examples of these propositions are:

(a) The relative advantage of RFID positively influences its adoption.

(b) The complexity of RFID technology negatively influences its adoption and

(c) That cost associated with RFID negatively influences its adoption.

The methodology used by Brown and Russell (2007) was to interview FMCG and retail stores with a significant national South African presence. Then a geographic bias was introduced to select only those companies in the Cape Town area where the researchers were based. Six stores were selected and subjected to a questionnaire and to a semi-structured interview. A 7-point Likert scale (1=Not at all and 7=To a large extent) was used to collect some data on some variables like cost, stock-taking. Most respondents thought that stock-taking was the biggest advantage of RFID, especially because of the instantaneous nature of RFID.

This took place in between July 2005 and September 2005. Two respondents from each organisation were chosen, one from the IT department and one not. This yielded a sample size was 12. Brown and Russell (2007) determined the adoption status of each organisation.

The authors found that overall participants did not have the expertise to implement, integrate, maintain, and adapt to RFID. The respondents were however willing and able to develop the skills needed to implement RFID.

The authors also determined that organisational size does influence the adoption of RFID. Here size was equated to be the number of employees. The paper concludes that the perceived view of RFID is that it is still technologically immature but it was on the respondents' "*list of things to do*".

When the research was conducted in 2005, it is significant to note that no company in the sample had planned to conduct or had conducted a pilot. So the study is really based on a sample of non-adopters although there was evidence that companies were seriously considering installing RFID in the future. Brown and Russell (2007) indicate that organisations in the South African retail sector do, however, have RFID in their plans with regard to "future-proofing" their ICT infrastructure for RFID.

4.3.4 RFID and Logistics

Lee *et al.* (2007) examine RFID in organisations in an intriguing context. They analyse and assess the extent to which companies receive (or are sent) tagged items. The questionnaire used by the researchers asked if the respondent: firstly, received RFID-enabled items (and used or ignored them); secondly, sent RFID-enabled items (as a customer requirement, but used or ignored them); thirdly, used RFID-enabled items internally but did not send them. Most literature refers to the last type as a closed-loop operation. These researchers use the more academic and appropriate term *in-bound logistics* to discuss RFID and its use in supplier-facing activities, and they use the term *out-bound logistics* to discuss customer-facing logistics, and they finally use the term *operations* to discuss the physical creation of the product or service. Smith (2005) calls this model the relation between RFID and CRM. He describes a work environment that freed time for more interaction between employees and customers that always had what a customer wanted, where perishables did not perish, where theft was detectable and where transfers were automated and precise.

Lee *et al.* (2007) assert that the majority of early applications of RFID have focused on the inter-organisational linkages between end-product manufacturers and their customers or the tracking of materials between locations. They conducted studies in service verticals, *inter alia*, Library System and its services and Road running which are discussed in this chapter.

The researchers reminded readers that RFID should be looked upon as an enabler in the provision of service: Finding a library book quickly or finding an unused ECG machine immediately. They found that using RFID has improved the value as perceived by customers.

They use an interview protocol with the data collection divided into three parts: firstly, general organisation; secondly, current use of RFID; and thirdly, future use of RFID. Between three and five respondents were used in each vertical. The authors also participated, as end-users in these two verticals: library systems and sports vertical. The profile of the respondents was not specified. Lee's *et al*. methodology (2007) is discussed further in Sections 4.3.5 and 4.3.7 respectively.

This study and indeed literature review affirm that most *current applications* that is deployed and used, are actually closed loop services, slap-and-ship exercises or niche operations, not supply chain interactions.

4.3.5 RFID and the Library

Lee *et al.* (2007) and Thakur (2007:a) independently report that most libraries revere RFID to deliver services. Lee *et al.* (2007) report that it is possible to inventory up to 5 000 books an hour using RFID. They report that the first inventory with RFID at a library found 300 "lost" or "missing" books. They also found that at least 130 libraries in the USA had used RFID by 2004. They reflect that a library in a customer-facing model uses RFID to issue, store and inventory books. In a service model libraries use RFID to store and restore books to their correct places.

Retief (2005) in a case study at the University of South Africa (UNISA) examined "the role on inventory control in service quality in a South African academic library." The study attempts, firstly, to determine the actual number of items found through mis-shelving and, secondly, to pinpoint the exact number of missing, mutilated and stolen items and, finally, to predict vulnerable information resources.

One of Reteif's recommendations (2005) is that inventory control is crucial and RFID must be considered as a way to reduce the cost of inventory control, reduce shelf reading time and improve the accuracy of inventory process.

4.3.6 RFID and the Automobile Sector

Schmitt *et al.* (2007) and Johansson and Annebäck (2005) conducted a comprehensive review of RFID and its use in the automobile industry.

Schmitt *et al.* (2007:2) lament that "in contrast to the overwhelming number of trade papers and white papers on RFID there is a surprisingly poor number of conceptual empirical research contributions on RFID."

These researchers attempted to identify factors that either impede or facilitate the adoption of RFID with a systematic detailed literature review. They found over a hundred factors that impact ICT diffusion in general. Then by case studies, literature review, interviews and workshops they reduced this number down to five factors for RFID diffusion: compatibility, complexity, costs, performance and top management support. This is very close to Rogers' generic model, providing further validity, and durability to this theory.

RFID has had exemplary adoption (total or saturated) in the vehicle immobiliser transponder market since the 1990's. This is a deep endorsement to the extra security that RFID can offer to vehicle access (Schmitt, 2007).

They reflect that the automobile industry uses a combination of modern supply chain methodologies like make-and-deliver-to-order, zero-error-production, lean management, just-in-sequence (JIS), and just-in-time (JIT) production to reduce costs and reduce cycle time. This is like the construction model discussed in 4.3.2.

They also explain that a closed-loop operation is a system with RFID transponders that are attached to an object and remain on it while it is shipped or moved within a cycle. The tag is returned to its point of origin when the object leaves the loop. This means the tag may be reused with the next object. Typical examples are valuable assets, for example, laptops, tools, returnable containers and pallets. It is noteworthy that they report that international car manufacturers Toyota, DaimlerChrysler, BMW and Volkswagen use RFID in closed-loop operations.

According to Schmitt *et al.* (2007) possible reasons for the low-diffusion of open-loop systems are the high failure rate of tags, the high costs of tags, the complex 1:n relationships in automobile supply chain, the need for widespread infrastructure, the lack of standards and the reluctance to share production detail with suppliers that coincidently also work with opposition vehicle manufacturers.

Johansson and Annebäck (2005) undertook a detailed literature review of RFID and then tied this to the two industries: automotive and pharmaceutical. An interview was conducted in person with eight people. A total of 14 people were also telephonically interviewed in the period November 2004 to February 2005. To restrict the sample size only those with the largest perceived influence on the supply chain were chosen. The interviewees were offered anonymity as a condition of the interview.

The case study finding was that Volvo and Volkswagen pilots indicate that a saving of 15% is possible.

4.3.7 RFID and Sporting Events

Lee *et al.’s* study (2007) in sporting events asserts that RFID has increased spectator enjoyment, has improved operational efficiency, and has increased the overall capacity of events. In the Lee *et al.* model (2007) this type of activity is referred to as a customer-facing model that makes the life of the customer (athlete) easier, but it also makes operations easier.

The paper cites a case study, the 10km Road Run, which has 25 000 runners and 17 000 walkers. In a typical race an athlete is issued with an RFID enabled tag which they wear on their wrist or ankle as a strap. As they run, strategically placed readers pick out the tag number and determine their real-time current race times.

Lee *et al.* (2007) assert that RFID has fundamentally changed the race experience, enabling their *actual* start and *finish* times and therefore their respective real race time to be available to *every* runner, not just the elite top runners. The authors observed that this intervention reduced the number of volunteers at the finish by 50 people. The volunteers used to gather information for each and every finisher. It needs to be borne in mind that these are tired sweaty runners who have just run 10km. Lee *et al.* (2007) also suggests that spectatorship at events also benefit from RFID.

Karaiskos *et al.* (2007) in a thorough and well structured paper examined user acceptance of pervasive RFID based ticketing system information systems. They did this by conducting a laboratory experiment with 71 participants. Karaiskos *et al.* (2007) call this the Technology Acceptance Model (TAM).

The participants were invited for a series of tests involving purchasing a ticket to an athletic event, using RFID tickets to gain access to a stadium (virtual tests). This involved testing system functionality. They were then asked to fill in a form to record on their experience. Each test was 30 minutes long.

Their study highlighted that the features of usefulness and ease of use are the dominant factors in assessing behavioural intention towards the model. The participants were willing to adopt the product if it became available.

4.3.8 RFID and Apparel

Koh *et al.* (2006) in a rigorous and methodical paper entitled "The Impact of RFID in Retail Industry: Issues and Critical Success Factors" carried research with the following objectives: (a) To identify underlying dimensions of perceived RFID benefits and risks for the retail industry and (b) To estimate a structural equation model for examining the relationships among RFID intrinsic attributes, perceptions of RFID such as benefits, risks, and its strategic impact on business performance.

These researchers identified four major categories of RFID benefits: (a) improved inventory management, (b) velocity of retail cycle, (c) integrated business model, and (d) efficiency of store operation. In addition, three major risk factors were recognized: (a) lack of technical expertise, (b) complexity of the technology, and (c) uncertainty of the technology.

This research explores RFID in the retail industry, and postulates a structural causal relationship among its intrinsic attributes, perceptions, and impact on business performance. A focus group of select industry experts was used to develop the research model. Based on findings from the focus group and a literature review, a survey instrument was developed to validate this research model empirically. Data was collected from seventy industry executives and managers. The data was analysed using exploratory factor analysis, confirmatory factor analysis, and structural equation modelling.

Koh *et al.* (2006) conclude with the sage advice that as RFID matures, and our understanding of the technology improves, more studies with rigorous design and methods will contribute insight on many questions unanswered by such studies. They note that "there is a need for an industry-wide effort to establish technical and business standards, identify and publicize business models, and educate all stakeholders on the potential and peril of the technology."

4.4 RFID in different countries

As this research effort focuses on South Africa, it is prudent to examine the effort of other researchers in RFID in South Africa and in other countries.

4.4.1 RFID Diffusion in Italy and Germany

Knebel *et al.* (2006) studied RFID adoption in Italy (2006) and Germany (2008). They looked at perceived CIOs attitude to RFID, current RFID usage, the intention of companies to invest in RFID and their vision of RFID application. Knebel *et al.'s* (2006) research contributed quantitative data on IT decision makers' view of RFID across various industries and company sizes in Italy. The study notes that RFID is currently not very widespread and many IT decision makers have not even heard about it. Those who have thought about the topic perceive RFID as a strategic issue.

In all 157 IT decision makers were interviewed. They asked many questions on the diffusion of RFID and some have been used as a basis for this research. Some of the findings were that 6% had implemented RFID, 1.5% was planning to implement, 3.3 % were building an RFID implementation and a third (33%) had not heard of it. The respondents felt that RFID would lead to improved customer service, reduce errors and optimize stock keeping. They also found that while RFID was considered important (8%), other issues, like Business Intelligence (15.4%) and CRM (18%), were considered more important.

The success of this paper led to them replicating this study in Germany. As this was done in Italy and Germany, some parts were replicated in this thesis in South Africa.

Jahner *et al.* (2008) conducted a study in Germany with a sample of 463 respondents. This study is similar to the Italian one and shares two common researchers. Drawing from literature on innovation, strategy and culture the objective of this study is to explore the role of perceived potentials and perceived strategic importance on CIOs' perspective on

RFID technology in two different cultural settings. The methodology is based on survey responses (Jahner *et al.*, 2008).

In total, 463 companies of various industries and company sizes took part in the survey (return rate 14.6%) in the German sample. The industry most represented was manufacturing (36.9%). Other relevant industry groups were automotive (18.4%), services (16.0%), retail (14.3%), consumer goods (11.7%), IT (11.7%), transport and logistics (11.0%), pharmaceuticals and healthcare (8.4%) and miscellaneous (22.9%). Companies with fewer than 2 500 employees represented almost 75% of the participating organisations. Most respondents are CIO's (72 %).

The results reveal that "RFID diffusion is very low" and that awareness is also low.

4.4.3 RFID Diffusion and China

No study will be complete without the market driver China. Hutchinson and Zhang (2005) conducted a field interview and panel discussion to get RFID of the ground. They present examples of successful RFID deployments.

They conclude that there are many challenges for RFID in China such as cost, standards, business environment, and untested market. But the opportunities are market size, advances in several industries, increase in logistics demand and China's role as a world-class manufacturing centre. Hutchinson and Zhang (2005) cite a survey which found that in a sample of 90 US companies, 40% of the manufacturers and 10% of the retailers had RFID timelines. Furthermore, a reported survey found the following reasons for non-deployment of RFID: costs (60%), standards (42%), untested market (36%) and integration issues (30%).

There is a concern that China may just go on with RFID on its own and invent its own numbering system due to the apparent slowness of the emerging standards. This is discussed elsewhere in the thesis.

Indeed China with its RF ID (sic) project now boasts to be the "world's largest" RFID-enabled government.

4.4.4 RFID Diffusion and SADC

Thakur (2007:b) conducted a literature survey of RFID and considered the benefits of RFID in geographic regional economies like SADC, the Southern African Development countries. SADC consists of all countries in the Southern sub-Sahara. The paper examines RFID and the opportunities it presents with respect to free movement of citizens and goods, its impact on a free trade zone, cross-border vehicle tracking, monitoring and livestock. He cited how Botswana has converted RFID technology into an opportunity. Botswana very neatly converted this strong EU recommendation for tagging livestock into opportunity in livestock by tagging (and tracking) every animal with RFID from birth to slaughter. When South Africa, which generally does not do tagging, has an animal viral outbreak like mad-cow disease, swine fever or equine flu, almost *all* animal exports cease. In Botswana, however, the use of RFID retains the international market confidence and export is selectively stalled (Thakur:b, 2007). Certainly international trends support this view as China has decided to tag all pigs and Australia has legislated the use of RFID in livestock.

According to Thakur (2007:a) SADC could influence the diffusion of RFID technologies if any of the listed possible usages of RFID offer an opportunity and meet a need. Legislative support will fast track diffusion of adoption *and* propel the region into the world stage but has legal and technical and ultimately cost implications.

Thakur reflects that other countries such as Australia has already legislated that all animals must be tagged. He points how a Singapore experience may be imported and translated into an African experience. In Singapore hospitals all patients and staff have RFID-enabled tags to record who was in close proximity to whom just in case an illness is determined to be highly infectious such as the bird flu or the H151 virus. This is far more efficient than outright isolation and it keeps the hospital open, which is a vital need. A Singapore-type intervention will be in useful in Africa during outbreaks of cholera, ebola or the current severe strain of malaria.

4.4.5 RFID Diffusion and South Africa

Moorgas (2007) found that RFID has gained momentum by the year 2006 year but that it will be some time before RFID is used in predictive business capabilities that may be embedded into supply chains down to item level. This now reflects a swing from

Plaggenborg's (2003) positivity that RFID will be "adopted in a few years" in 2002 to Moorgass's (2007) somber assessment that RFID will "not be adopted for few more years" in 2007. This vacillation is the story of RFID.

Moorgas's thesis is a clever justification that uses a literature review technique to find the critical success factors addressing the adoption of RFID. The justification of the relevance of the factors is that as peer-reviewed papers were selected, their work must have been valid. Moorgas finds literature support for his findings that "a full SCM is unlikely in the coming years" in South Africa. Indeed he reaffirms this researcher's conclusions that "closed loop would be the most successful."

The Brown and Russell (2007) experience is also uniquely South African but it is reported in Section 4.3.3.

Korteweg (2007) confidently asserts that "On national level, in South Africa research on adoption characteristics of organizations and their perception towards this technology does not exist." He interviews 14 companies in 6 verticals. He found that that RFID awareness was growing but usage limited to transport and then only in a "closed-loop." A flaw here was that he chose market leaders in each segment and then considered "them to represent the industry." Innovators hardly innovate to be representative.

4.5 Strategic and Organisational perspective on RFID

Sharma, Citurs and Konsynski (2007) studied strategic and institutional perspectives in the adoption of RFID. They conducted in-depth, semi-structured interviews of executives and RFID program managers and supply chain managers across ten organisations that have been associated with RFID initiatives. To avoid single response bias, some interviews were conducted with multiple respondents from the same organisation. Each interview was conducted face-to-face or over the telephone for about 1-2 hours. This paper informed the choice to the researcher of using a Knebel *et al.* type CIO study but with a Sharma *et al.* methodology of more than one respondent.

They show that perceived potentials of RFID influence the perceived strategic importance which positively influences CIOs' intention to invest in RFID. The composition of perceived potentials affecting the strategic importance of RFID differs significantly in both cultures. Results revealed that the potentials attributed to RFID differ significantly in different cultures. In Germany, potentials attributed to RFID are improving quality, automating manpower, reducing counterfeits, and improving customer service. Italian CIO's value reducing stock inconsistencies, optimizing stock keeping, and improving customer service as RFID potentials. Regardless of culture, findings show that company size hardly has an impact on perceived strategic importance.

4.6 RFID and Security

4.6.1 RFID and Hacking

Tanenbaum *et al.* in an award winning paper (2006) showed how an RFID tag can be hacked. Tanenbaum's authority in Data Communications is acknowledged. However, this paper was attacked by RFID experts for making too many juvenile assumptions that could make such attacks possible. Regrettably, the rebuttal was not given the same prominence as the claim. In fact, their website that *still* celebrates this award does not mention the rebuttals at all!

The Tanenbaum paper, does however, point to other possible security and privacy threats, listed below.

a. In a technique described as *sniffing* or *skimming* hackers exploit a feature that the tags are designed to be read by any compliant reader. Hackers could design a reader with software that can read a tag without the tag bearer's knowledge, and that this may happen over large distances. This could have implications for digital passports.
b. *Tracking* could be useful for senior citizens, kids and high value assets, but it may be used to track subjects involuntarily.
c. In *spoofing* attackers create authentic tags (clones) through appropriate formatting, sniffing and writing. This was done at John Hopkins University and the tag was used to buy gas and unlock another car immobilised with RFID.
d. In another technique known as *Denial of Service (DoS)* this happens when RFID systems are prevented from operating (Tanenbaum *et al.*, 2006).

This was done by laboratory tests.

Their contention was later disproved. This researcher maintains that as the paper was disproved rather than discredited, Tanenbaum *el al.*'s perceived lack of acknowledgement of this is unfortunate.

Rieback *et al.* (2006) in an engaging and non-technical manner examine the evolution of RFID security with particular reference to IFF systems (Identify Friend or Foe).

Weis (2003) engenders and provides a *dramatis personae* to Tanenbaum *et al.*'s *(2006)* intruder as the "Phyllis" type attacker. Phyllis is now accepted nomenclature for a "person(s) assumed to be able to obtain tags physically and conduct sophisticated attacks in a laboratory setting. Her attacks may include probe attacks, energy attacks, radiation imprinting, circuit disruption or clock glitching. Fortunately Phyllis cannot carry out her attacks in public or on a widespread scale.

The potential abuse of privacy due to the implementation of RFID is a regrettable unintended consequence of some extremely useful implementations. Although part of the proposition may sound ludicrous, the perception does exist so cognisance must be taken of it. Besides in marketing parlance, "perception is reality" consequently several interventions allow for stores (or consumers) to destroy tags automatically at store frontcourts. These are then unusable.

4.6.2 Other Potential RFID Security Problems

The Bumbak Master's thesis (2005) entitled "*Analysis of potential RFID security problems in supply chains and ways to avoid them"* again examined the supply chain and conducted an analysis of potential RFID security problems in supply chains and ways to avoid them.

Suppliers work hard to gain a competitive advantage. By having an open standard tag system, it may allow an unauthorized read. This can be completely unintentional as a reader is designed to read any signal that it understands and a competitor could end up with ones supply chain movement. The research question posed is: "What can companies do to avoid or combat security problems of RFID in their supply chain?" He determined the following problems and presented the following solutions:

Table 4.3 enumerates security problems encountered with tags in SCM along with some preventative methods and suggested problem handling techniques.

Table 4.3 Tables of security problems encountered with tags in SCM (Bumbak, 2005)

Problem (Related to data stored on the tag)	Prevention	Problem Handling
Unauthorised reading the tag	Minimise tag time exposure to SC outsiders Use cryptography	Assess real time and potential damage
Changing the data on a tag	Use write once tags Check your tags regularly for any changes Password protection	Return tag to original state Create backup storage in database
Eavesdropping on the communication between tags and readers	Employ existing surveillance systems to detect any attackers Use encrypted communication	Locate the eavesdropper and disable further action
Tag Integrity		
Physical damage / removal of the tag	Pressure sensitive labels	Not identified
Killing of the tag	No software killing	Replace tag
Denial-of-service attacks	Detection devices	Remove the interruption Use backups if available
Securing data related to the serial number on a tag	Implement IT security measures If already in place re-evaluate.	Response team

His methodology was to do a literature survey and then an interview of four experts in RFID, whom he profiles and identifies.

Remarks

As the researcher closed this effort, in October 2008, it was found that Researchers from the Dutch Radboud University have cracked and cloned London's Oyster travel card, after cracking the Dutch Mifare Travel card. This card would be used in a nationwide network for billing of public transportation. Both cards use the Mifare Classic RFID tags, which relies for its security on an algorithm that can be cracked with modest effort. The troubled card provides for contact-less entrance to public transportations and office buildings worldwide.

The manufacturer of the chip, NXP, followed Dutch Secretary of State Tineke Huizinga, lead in claiming that the publication of the results is irresponsible. The presiding judge concurred and the case is on appeal. This is now a tussle between academic integrity, law and security (EPC Report, 2008).

4.7 Conclusion

This chapter commenced by examining the publications rate in RFID. As the technology appears to diffuse on a sector-by-sector basis, it also examines RFID in different verticals such as logistics, and supply chain management. There is an emerging view that RFID has diffused in certain sectors such as automobile, event management and retail. What is also clear is that the diffusion is restricted to certain aspects of the vertical, for example, only in closed-loop operations.

As this study is tied to a geographic region of KwaZulu-Natal, South Africa, published RFID studies is examined for any parallel study in countries such as China, which is studied for its sheer size and potential influence; SADC countries, and, Italy and Germany. This geographic country-by-country analysis also reveals that RFID awareness and adoption is steadily improving.

Current and previous RFID diffusion studies are largely literature-based but there is some evidence of case studies and more empirically based studies. The literature studies are generally positive on the value that RFID can add; the low number of case studies reflects that converting the "promise of RFID" into delivery is difficult. Another area of consistent concern is cost, while many CIO's have simply not heard of RFID.

The next chapter introduces the Research methodology that is used in this thesis. It describes the research population, sampling process, the questionnaire and analysis.

Chapter Five
Research Methodology

5.1 Introduction

This chapter explains the process followed by the researcher in this study. It starts with the description of the research population and the sample selection process. The data collection process is then explained. Appropriate statistical tests for data analysis are presented. The research method of the survey is also described.

5.2 Research Population

The research population is all made up of KwaZulu-Natal businesses with at least 50 PC's in one site, that is, in a single location of the business. Many companies have more than 50 PC's but fewer have them in a single site.

The size of organisations is cited by existing literature as a compelling concomitant to innovativeness (Rogers, 1995). However, Rogers did not specify the exact nature of size. Many diffusion studies have equated size with the number of employees, or with turnover, or with the number of assets, or with the number of branches. In this study **size** was chosen to be the number of PC's in a geographic unit of the organisation. The rationale behind choosing companies with 50 or more PC's is that such companies may have the "technological critical mass" to enable the introduction of a new technology like RFID.

A strategic database called Matrix Marketing was used to identify companies with 50 or more PC's. Matrix Marketing is a South African business information database with approximately 80 000 companies across all industries in South Africa. It contains approximately 165 000 names of executives and decision makers. This database contains the name, email and telephone number of senior ranking members of the organisation, for example, Managing Director, Chief Financial Officer and Chief Information Director. There were 140 organisations in Matrix Marketing categorized as KwaZulu-Natal companies with at least 50 PC's in one site.

All of these 140 companies were personally telephoned by the researcher and asked if they were aware of RFID. If they were aware, they were then asked if they piloted an RFID project, currently use RFID, or used and rejected RFID and, finally, whether they decided not to use RFID at all. The companies were contacted over the period from April to May 2008. The person contacted was usually the CEO, the CIO or the CFO, thereby ensuring that participants' responses were from authoritative sources. Needless to say, it may be possible that some respondents did not want to participate and simply said that they had never heard of RFID in order to stop the telephonic interview.

Only 130 volunteered information during the telephonic survey. Therefore, the remaining 10 respondents are excluded from the discussion.

5.3 Sampling

This section describes how the research sample was computed, how its size was determined, and how the random sample was selected. It introduces and explains the categories called adopter and non-adopter.

5.3.1 Sample Selection Methods

In order to get a sample size for a normally distributed sample and with a confidence level of 95% and with a confidence interval of 3 from a population of 130, a statistical calculator, provided as Web Service, was used (WebService, 2008a). This applet indicated that 116 companies must be randomly selected.

A random table was then used according to the method suggested by Johnson and Kuby (2005) to determine which 116 companies to survey. The random table chosen had a bank of 25 random numbers with values from 0 to 100. 14 values were taken from these 25 random numbers and these were used to exclude companies from the survey list, 130-14=116, to make the sample size random and appropriate. This is the first sample of 116 companies for the purpose of answering Research Question One on the Diffusion Rate which is in Chapter One, Section 1.4 (a).

5.3.2 Adopter Sample and Non-adopter Sample

During the telephonic survey respondents were invited to participate in the next phase of the research. A total of 21 companies agreed to participate with 11 RFID adopters and 10 non-adopter RFID companies.

Companies were given the option of being represented by more than one respondent. This was to remove a respondent's bias because more than one respondent will represent a more diverse view. This diverse view was anticipated as the respondents were granted anonymity. This produced a total number of respondents of 30. The 30 respondents were divided into two samples:

An adopter sample with 16 participants; and
A non-adopter sample with 14 participants.

The adopter sample was made up of participants from RFID-adopting companies and the non-adopter sample was made up from companies which did not adopt RFID.

A table with the distribution of number of participants per company follows.

Table 5.1 The distribution of participants in each category

Adopter Company Number	Number of Participants
1	1
2	1
3	1
4	1
5	1
6	3
7	1
8	1
9	3
10	2
11	1
TOTAL	**16**

Non-adopter Company Number	Number of Participants
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	2
10	4
11	
TOTAL	**14**

5.4 Research Method

This research consists of two consecutive surveys: a telephonic survey followed by a questionnaire-based survey. The population and the sample for the two surveys is explained and defined above. The purpose of the telephonic survey was to determine the diffusion rate. The purpose of the questionnaire-based survey is to examine the perceived commonalities and differences between adopters and non-adopters with regard to various independent variables. These variables are defined in the next section on data collection.

5.5 Data Collection Method

There are three methods used in this study, depending on the research phase, namely, the *Internet*, which was used to determine the research population; the *Telephone*, which was used to interview the sample; and the *Questionnaire*, which was used for the comprehensive research participants.

5.5.1 Internet

An Internet-based database was mainly used to select the 140 companies in the research population. There is a propriety database web-service called Matrix Marketing that outputs the profile of companies according to specific criteria input by the user.

5.5.2 Telephone

The companies in the research population were contacted by telephone during the month of April and May 2008. Usually the CIO was the person contacted. Each call lasted for an average of three minutes. Most CIO's were, in general, cooperative except for 10 respondents who declined.

The theme of the telephonic call was to enquire from the respondents if their company was aware of RFID and, if so, what their level of usage was. Besides establishing a rapport with the CIO, an unintended result of the telephonic conversations was the unearthing or discovery of the usage of another Auto-ID technique, Electronic Article Surveillance or EAS. In terms of the description of diffusion by Rogers, this discovery by the researcher is deemed to be an innovation for the researcher.

It is worth noting that the telephone was also used where clarification was needed on filled questionnaires.

5.5.3 The questionnaire

A comprehensive questionnaire was compiled and used as the basis for data collection for the second phase of the research. Although various sources informed the design of the questionnaire, the most comprehensive input has been Curtin *et al.* (2007). The visual format of the questionnaire is based on an admirable effort by Huchzermeier and Sachon (2006) and some of whose questions were also used.

The participants in the survey were invited for sessions lasting up to three hours. In these sessions respondents were afforded an opportunity to fill in the survey questionnaire**.** During the sessions participants were afforded the opportunity to ask questions on aspects of the questionnaire that were unclear. Refreshments in the form of lunch and cool drinks were provided to make the task less onerous. These sessions succeeded in attracting 20 respondents. The remaining 10 respondents were individually visited by the researcher.

A copy of the questionnaire may be found in Appendix One at the end of the thesis. The approach used to elicit a response is primarily the 5-point Likert Scale (1=Not at all, 5=To a large extent). The questionnaire is produced verbatim in Appendix One. Of interest to this research is the following: bibliographic data, RFID Experience, Strategic variables, awareness of RFID, and Critical success factors. These are explained in the next section.

5.6 Research Variables

An analysis of the questionnaire reveals that the dependent variable is the adoption status and the independent variables may be grouped under the following categories: bibliographical data, RFID experience, strategic importance of RFID, and critical success factors.

5.6.1 Dependent variables

The adoption status indicates the action a company took with specific reference to RFID. These actions are categorised as piloted, piloted and rejected, adopted, or not using RFID at all. For the purposes of categorising *all* companies that piloted, piloted and rejected, adopted were considered adopters and all that did not use RFID is the non-adopter group. This rationale is explained in Diffusion Theory in Chapter Three.

5.6.2 Independent variables

5.6.2.1 Bibliographical data

This includes variables such as name of the company, age of the company, vertical and turnover. This data was captured through Section A, called Organisational Profile in the Questionnaire in Appendix One.

5.6.2.2 RFID experience

This looks at the experience of the respondent with respect to reading about RFID, RFID workshops attended, respondent's role in RFID projects, and actual integration experience of RFID. This data was captured through Section A, called Organisational Profile, and Section B, called Participant Profile, in the Questionnaire in Appendix One.

5.6.2.3 Strategic variables

The value of the strategic variables becomes more significant if there are tests of perceptions between the adopters and non-adopters on the *same* variable.

The survey captures the perceived strategic importance of companies by respondents on the following variables: Instant inventory, Reduction in labour requirements, Reduction in pickers or picking time, Reduction in data capture time, Elimination of some errors, Labour cost savings, Lower stock-outs, Less shrinkage, Less theft. This data was captured through Section C, called RFID Adoption, in the Questionnaire in Appendix One.

5.6.2.4 Contextual awareness of RFID

This determines the applicability of RFID to respondents business. Two specific variables are tested: "Don't know RFID well enough at this stage" *and* "To my knowledge, RFID is not applicable in our business". This data was captured through Section C, called RFID Adoption, in the Questionnaire in Appendix One.

5.6.2.5 Critical success factors

The respondents (adopters and non-adopters) were given the opportunity to rate each of the aspects on a 5-point Likert scale (1=Not at all, 5=To a large extent). The data is captured by Question 10 in the Questionnaire. It includes the following variables: Support concerns, Cost, Human skills non-availability, Implementation costs, Corporate resistance, Support concerns, RFID does not feature in my rank of priorities, Knowledge of other RFID implementation failures, Legislative concerns, Non-availability of standards in RFID, Non-availability of ICASA spectrum, Privacy issues, Security issues, Legislative issues, Other innovative solutions like 2-D barcode, Barcode is good enough for our applications, Time consumed to change the system, Extra training for employee, Technology unproven or immature, Human skills non-availability, Implementation costs, Corporate resistance. This data was captured through Section C, called RFID Adoption, in the Questionnaire in Appendix One.

5.6.3 Vertical analysis

The two categories in the sample came from the following business verticals: Sugar related activities, Sports and Events, Cold Storage, FMCG, Manufacture, Government, and Library Systems. The sample sizes in each vertical are small but provide an opportunity for some descriptive cluster analysis.

5.6.4 Research approach

The approach is mainly qualitative although quantitative data is also used. Quantitative data refers to variables such as turnover, age of company etc; bibliographic data are variables such as name, website, etc. For the purpose of analysis the qualitative 5-point Likert scale is interpreted as a discrete value with: (1=Not at all, 5=To a large extent). But the average or mean was interpreted as a continuous one, that is, the qualitative value is converted into a quantative one.

5.7 Data Analysis

The data analysis is performed mainly through statistical methods, which are expressed in the form of hypothesis. These were tested.

In Statistics, a test statistics is a function that produces values from data for comparing with expected values under various models. Two types of test statistics were used in this research: the proportion hypothesis and the comparison of the means of two independent samples with unequal variance. As these test statistics are frequently used, the methodology is introduced and discussed next.

The next section describes how the test for two proportions was conducted. This model is extensively explained in the Excel Package and statistical web services such as StatTrek (Webservice, 2008b).

5.7.1 Testing the proportion hypothesis

This section explains how the adoption rate, relative to Roger's adoption Curve of RFID was statistically computed.

Statistic

The following formula is used. This is called *a test for two proportions*.

$$\sigma = \sqrt{\frac{P * (1 - P)}{n}} \quad and\ Z - score = \frac{p - P}{\sigma}$$

This statistic is used when one wishes to determine population behavior when one knows this particular behavior in a sample (or proportion). The test results were validated by using the Web Service provided by StatTrek (Webservice, 2008b).

The data analysis is mainly statistical which is expressed in the form of hypotheses. These were tested.

Two types of statistics were used: the proportion hypothesis and the comparison of the means of two independent samples with unequal variance. As these are frequently used, the methodology is introduced and discussed here.

This test was validated by using the Web Service provided by Stat Trek (Webservice, 2008b).

- **State the hypotheses.** The first step is to state the null hypothesis and an alternative hypothesis.

  H_o: P=19% ; the proposed proportion

  H_1: P≠19% ; the proposed is not correct

  This hypothesis constitutes a two-tailed test. The null hypothesis will be rejected if the sample proportion is too big or too small.

- **Formulate an analysis plan**. For this analysis, the significance level is 0.05. The test method, shown in the next section, is a one-sample z-test.
- **Analyse sample data**. Using sample data, calculate the standard deviation (σ) and compute the z-score test statistic (z).

$$\sigma = \sqrt{(P * (1 - P) / n)}$$

$= \sqrt{[(0.19 * 0.81) / 116]}$

$= \sqrt{(0.0013)}$

= 0.036

z = (p - P) / σ = (.12 - .19)/0.036 = -1.92

Where P is the hypothesized value of population proportion in the null hypothesis, p is the sample proportion, and n is the sample size.

Since we have a two-tailed test, the P-value is the probability that the z-score is less than -1.92 or greater than 1.92.

Use the Normal Distribution Calculator to find $P(z < -1.92) = 0.027$, and $P(z > 1.92) = 0.027$. Thus, the P-value = 0.027 + 0.027 = 0.054.

- **Interpret results**. Since the P-value (0.054) is greater than the significance level (0.05), we cannot reject the null hypothesis.

5.7.2 Method for testing the difference between the means of two independent samples with unequal variance

This research has two categories or samples: Adopters and Non-adopters. It is appropriate that the perceptions of the two categories be compared for the various variables. This is reasonable as there must be *some* difference for there to be two groups, otherwise they will be homogeneous. On the other hand, understanding the similarities and commonalities between the two categories helps in understanding the adoption process better.

This uses *the comparison of the means of two independent samples where the variances are unequal test* as described in the data analysis pack of Microsoft Excel. It is equally important that the authenticity of the results were separately tested on the StatTrek system and found to be identical. Microsoft Excel was chosen for the neat, easy-to-format output.

Where a statistic is computed, the *N* refers to the number of respondents where the researcher got the appropriate answers through the questionnaire or interview. Some omissions in the questionnaire happened in cases where a respondent did not know, or declined to answer, a specific question. It is for this reason that *N* varies.

The following menu option was used in Microsoft Excel.

Microsoft Excel > Analysis ToolPak > **T-Test Two Sample unequal Variances**

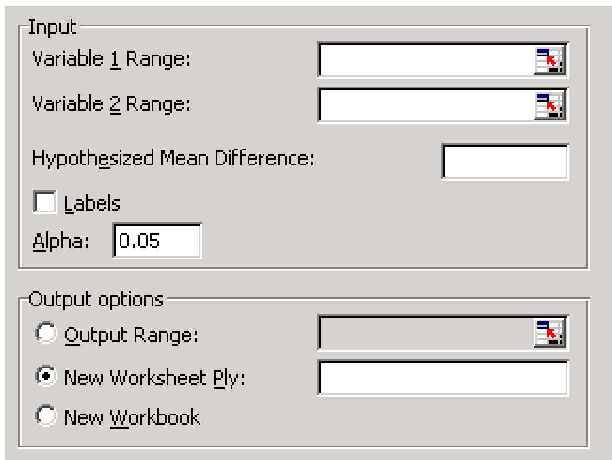


Figure 5.1 Statistical Tool (Microsoft Excel Data Analysis, 2008)

For completeness the formulae used by Microsoft Excel to perform the computation are provided below (BetterSolutions, 2008).

$$t = \frac{\overline{X}_1 - \overline{X}_2}{s_{\overline{X}_1 - \overline{X}_2}}$$

$$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

$$\text{D.F.} = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{(s_1^2/n_1)^2/(n_1 - 1) + (s_2^2/n_2)^2/(n_2 - 1)}.$$

The range corresponding to respondent data from *adopters* was placed in the Variable 1. In addition the range corresponding to respondent data from *non-adopters* was placed in the Variable 2.

Each of the fields that require input in Figure 5.1 is now described.

Variable 1 Range - Enter the cell reference for the first range of data to be analysed. The range must consist of a single column or row of data. *Used for Adopters.*

Variable 2 Range - Enter the cell reference for the second range of data to be analysed. The range must consist of a single column or row of data. *Used for Non-Adopters.*

Hypothesized Mean Difference - Enter the number required for the shift in sample means. A value of 0 (zero) indicates that the sample means are hypothesized to be equal.

Labels - Select if the first row or column of input ranges contain labels. Clear this check box if input ranges have no labels; Microsoft Excel generates appropriate data labels for the output table. *Used for formatting purposes e.g. Variable name.*

Alpha - Enter the confidence level for the test. This value must be in the range between 0 and 1. The alpha level is a significance level related to the probability of having a type I error (rejecting a true hypothesis). *The confidence level of 0.05 was used throughout this study.*

Output Range - Enter the reference for the upper-left cell of the output table. *Excel automatically determines the size of the output area and displays a message if the output table will replace existing data.*

New Worksheet Ply - Click to insert a new worksheet in the current workbook and paste the results starting at cell A1 of the new worksheet. *To name the new worksheet, type a name in the box.*

New Workbook - Click to create a new workbook and paste the results on a new worksheet in the new workbook.

T-test Two-Sample Assuming Unequal Variances. This analysis tool performs a two-sample Student's t-test. This t-test form assumes that the variances of both ranges of data are unequal; it is referred to as a heteroscedastic t-test. One may use a t-test to determine whether two sample means are equal. This test can be used as either a one-tailed or two-tailed test.

As an example we were interested in whether *Support Concerns* were perceived as a bigger problem by non-adopters than by adopters.

A complete design of a hypothesis will be presented so the Microsoft Excel Data Analysis method may be understood.

We wish to determine if the means of the adopter category is higher than the means of non-adopters.

The hypothesis is stated.

Turnover

Hypothesis 5.1 *The turnover of the adopters is significantly higher than the turnover of the non-adopters.*

Testing Hypothesis 5.1 on turnover

The null hypothesis and the alternate are also stated in a manner that will allow to determine the magnitude of the difference between the means.

H_o: $\mu_1=\mu_2$; There is no difference in the means for adopters and non-adopters.
H_1: $\mu_1 - \mu_2 \geq 154$

$\alpha=0.05$; *The confidence level is stated.*

The means of the two samples is computed and stated. The sample size is also stated. With Microsoft Excel, it is only necessary to state the start field of the adopter category and the non-adopter category and the means, μ_1 *and* μ_2 *and the sample sizes* n_1 *and* n_2 *are computed automatically.*

$\mu_1=2028.09$; for adopters
$\mu_2=495.79$; for non-adopters
$n_1=14$, $n_2=14$

The t-test is also computed and output in the format that exactly listed below.

t-Test: Two-Sample Assuming Unequal Variances

	Adopter	*Non-adopter*
Mean	2028.089286	495.7857143
Variance	7604286.169	1177610.797
Observations	14	14
Hypothesized Mean Difference	154	
Df	17	
t Stat	1.740262375	
P(T<=t) one-tail	0.04994103	
t Critical one-tail	1.739606716	

The t-statistic t* is 1.74026 and the $t_{(\alpha=0.05,17)}$=1.7396 As t* > $t_{(\alpha=0.05,17)}$

This result allows one to reject H_o and accept H_1 and conclude $\mu_1 - \mu_2 \geq 154$ or that the mean turnover of adopters of RFID is greater than the mean turnover of non-adopters.

5.7.3 Discussion on the layout for Hypothesis testing

The extensive nature of the questionnaire meant that many statistical tests were performed. For reasons of size, space and discussion clarity, it was decided simply to state the variables, the hypothesis, and the central statistics for the two populations, namely adopters and non-adopters.

Hypothesis 1: The general RFID diffusion in KwaZulu-Natal is currently estimated to be equal to 19% with a confidence level of 95% and a confidence interval of 3%.

The turnover of the adopters is significantly higher than the turnover of the non-adopters.

Hypothesis 2 - 4 are hypotheses that test the relationship between the two sample groups, the adopters and the non-adopters.

Hypothesis 2: The means of the adopter and non-adopter groups has no difference. This is exhaustively enumerated in Table 6.1 where the results are presented.

Hypothesis 3: The means of the adopter group is greater than the means of the non-adopter group. This is exhaustively enumerated in Table 6.3 where the results are presented.

Hypothesis 4: The means of the non-adopter category is greater than the means of the adopter category. This is exhaustively enumerated in Table 6.5 where the results are presented.

5.8 Conclusion

This chapter described the methodology used to examine the perceptions of RFID in a systematic way. This allows the researcher to get a bearing on perceptions of RFID.

It commences with the description of the research population and how the research sample was selected. The data collection process is then described and how the data would be gathered and analysed. Appropriate statistical tests for data analysis are then presented. As these statistical tests or methods are used very frequently, a comprehensive description of a hypothesis was presented along with explanations. The research method of the survey is also described. The next chapter presents the results of this study.

Chapter Six
Analysis and Results

6.1 Introduction

This chapter presents the research results. It answers to the research questions posed in Chapter One by testing the corresponding research hypothesis with the collected empirical data. The chapter starts with the presentation of the characteristics of the sample of the research.

6.2 Sample Characteristics

This section examines the characteristics of the respondents bearing in mind that each respondent can be described in two dimensions: as an individual, but also as a member of an organization within a given business vertical.

6.2.1 Business Verticals

Among the people who filled in the research questionnaire, 6 participants were from companies within the sugar industry, 4 participants were from the sports and events sector, 6 participants were from the cold storage sector, 3 participants were from the FMCG sector, 6 participants were from the Manufacturing sector, 3 participants were from the government departments, and 2 participants were from the library services sector. The total number of participants was 30.

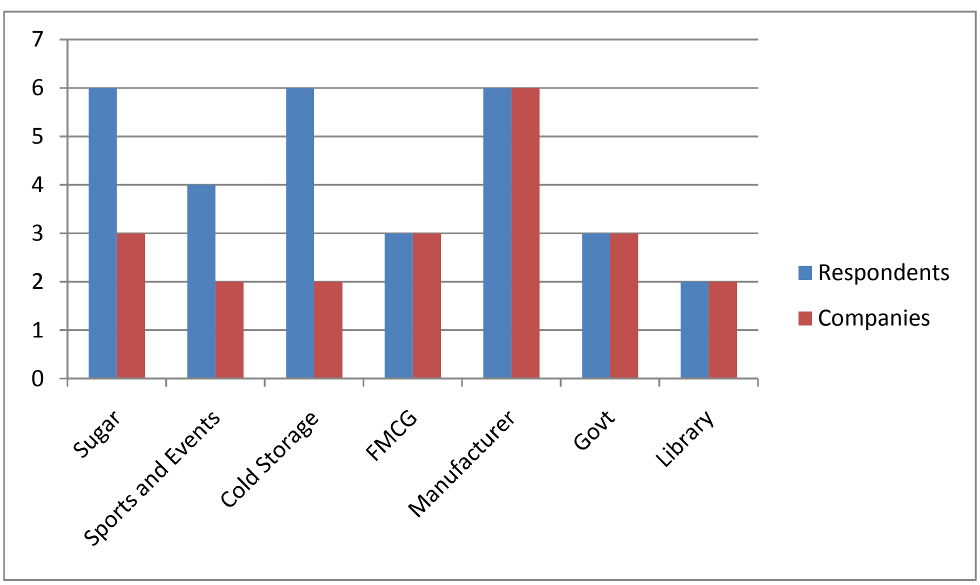


Figure 6.1 Distribution of the respondents into business vertical

Figure 6.1 is a graphical representation of the distribution of respondents but it also shows the distribution of participating organisations.

Among the number of companies that responded 3 participating companies were from the sugar industry, 2 participating companies were from the sport and events sector, 2 participating companies were from the cold storage sector, 3 participating companies were from the FMCG sector, 6 participating companies were from the manufacturing sector, 3 participating companies were from the government departments and 2 participating companies were from the library services sector. The total number of participating companies was 21.

6.2.2 Respondent Characteristics’

6.2.2.1 Participants’ Gender

It is worth mentioning that only one woman participated in the survey, which shows an overwhelming male gender bias in the participants.

6.2.3 Organisational Characteristics

This section describes some key business attributes such as age, location, multinational status, and the stock exchange presence of the participating companies.

6.2.3.1 Geographic Presence

The selection criterion for the sample was that companies must have an office in KwaZulu-Natal. The interest in this section is to establish the footprint of companies, that is, whether their company had a local, national or international presence. In the sample 8 respondents were from companies based only in KwaZulu-Natal, 4 companies with a national presence only, 8 from companies with both a national and an African presence, and 10 had an international presence. This sample is skewed as it has more than one respondent from some companies. On the other hand, this presented an opportunity to get more than one view from certain verticals.

6.2.3.2 Web Address

All the companies in the research sample have a web address and a physical office in KwaZulu-Natal.

6.2.3.3 Age

The average age of the company in the research sample is 35.20 years with four companies over 100 years old.

6.2.3.4 Listed

Eleven of the 21 respondents' companies were listed on the Johannesburg Stock Exchange.

6.3 Empirical Findings

This attempt to answer to the research questions based on the analysis of the collected empirical data.

6.3.1 RFID diffusion rate

One of the questions introduced in Chapter One of this study is to find the RFID diffusion rate in the population studied. Indeed the first research question posed is the following:

> **Research Question One** *What is the RFID diffusion rate?*

This study reveals two types of diffusion rates: firstly, the general diffusion rate which refers to RFID diffusion in KwaZulu-Natal for the population of 116 companies with more than 50 PC's; and secondly the diffusion rate which refers to the diffusion rate per vertical.

6.3.1.1 General diffusion rate

An analysis of the diffusion rate in the 116 businesses in the sample shows the following:

14 companies are using RFID (12.1%)
92 companies are not using RFID (79.3%) (This includes companies reporting that they have not heard of RFID)
5 companies are in a pilot with RFID (4.3%)
1 company has piloted and rejected the solution (0.9%) and
4 companies are using EAS tags (3.4%).

This result is shown graphically in Figure 6.2. It appears that the number of companies not using RFID is quite large. The 3.4 % of EAS users was a surprise to the researcher as this is also a form of Auto-ID.

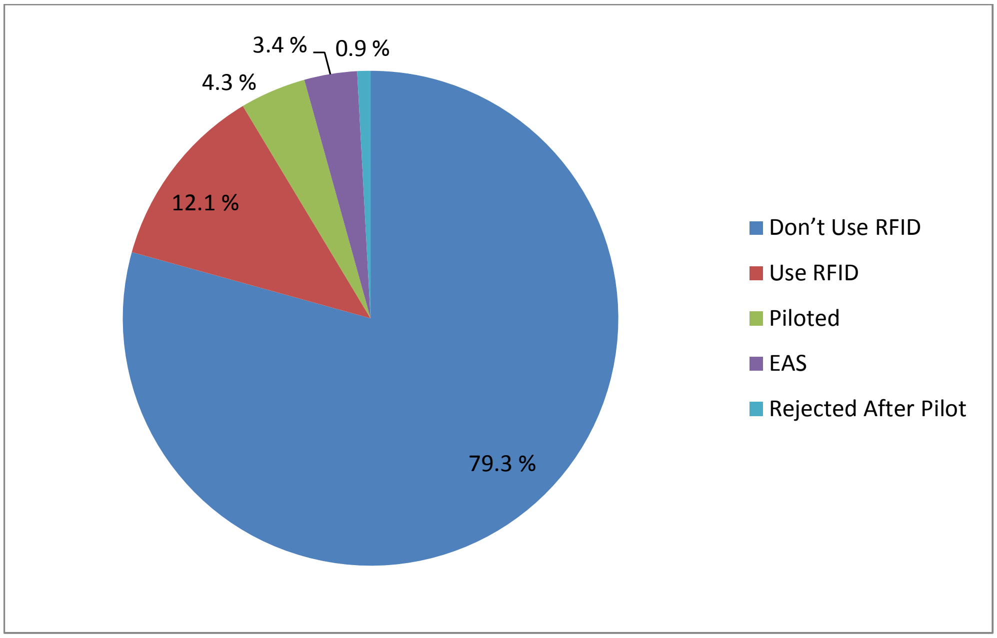


Figure 6.2 Adoption patterns of RFID determined by a telephone survey

If one adds the proportion of companies using or having piloted RFID, then one can formulate the hypothesis according to which RFID adoption rate in the research population is estimated at 19%. This is done by Hypothesis 1.

Like any hypothesis, Hypothesis 1 must be tested in order for it to be proven true or false.
Hypothesis 1 *The general RFID diffusion in KwaZulu-Natal is currently estimated to be equal to 19% with a confidence level of 95% and a confidence interval of 3%.*

Testing Hypothesis 1

H_o: P=19 ; the null hypothesis
H_1: P≠19 ; the alternate hypothesis
α =0.05 ;
P =19% ; The percentage that is postulated to be using RFID
p =12% ; the percentage that is using RFID from our research sample in figure 6.2
n=116 ; the sample size.

The decision on the acceptance of the hypothesis depends on the calculation of the z-score value whose formulae is

$$Z - score = \frac{p - P}{\sigma} = \frac{0.12 - 0.19}{0.036} = z = -1.92$$

Where p is the adoption rate in the sample, (p=12%). P is the adoption rate as per the hypothesis (P=19%) and

$$\sigma = \sqrt{\frac{P * (1 - P)}{n}} = \sqrt{\frac{0.19 * (0.81)}{116}} = 0.036$$

In this case, the calculation of z-score= z = -1.92 and σ = 0.036

p-value is the probability that sample is drawn from the population and its formula is

p-value = 2 * P(z< -1.92) = 0.055

Since p-value is greater than the level of confidence, one cannot reject the null hypothesis for Hypothesis 1 (α =0.05).

The null Hypothesis H_o for Hypothesis 1 is therefore *accepted*. Hypothesis 1 is therefore deemed to be true.

6.3.1.2 Adoption status on Moore's Curve

Hypothesis 1 indicates that 19±3% of the research population have adopted RFID. And the Rogers' adoption curve shown by Figure 6.3 indicates that the chasm is crossed when the adoption rate reaches 16%. Therefore one can conclude that RFID has crossed the chasm.

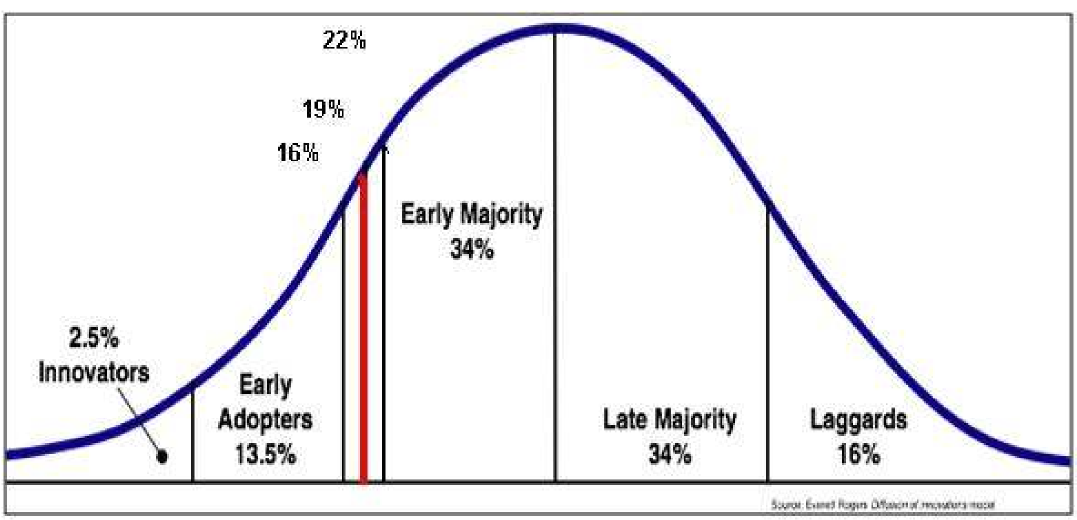


Figure 6.3 Moore's Technology Adoption Curve

6.3.1.3 Diffusion rate, status, use of RFID per vertical

The sample sizes are very small for the clusters analysis. The method of analysis is therefore descriptive, which is RFID adoption in these clusters. The verticals considered are, *inter alia*, library systems**,** sugar industry, sport and dairy and cold Stores: in the sample of 116 of companies.

6.3.1.3.1 Library Systems

The two libraries participating in the research acknowledge that they use EAS tags. Therefore libraries will enjoy total RFID diffusion (100%) in the library sector if the sample were representative of the entire library sector. They currently use EAS but only in closed-loop operations.

The library is a stunning example of success in adversity. Librarians always struggle for funding in any environment, and most certainly in a South African context, yet they already work with EAS tags. This is a sign of an incremental advancement. The knowledge they gain from this advancement will stand them in good stead when they eventually adopt RFID (Thakur, 2007:a). In Von Hippel's model (2005), Libraries are way ahead of other verticals: they *really* want RFID. Almost all librarians are early majority users of technology (Von Hippel, 2005). This may be because they are service oriented with regard to their processes and constantly think of ways of enhancing the borrower's experience (Lee *et al.,* 2007). However, the libraries now desire the newer read-write RF and they want it soon. They want RFID as long as it works without contrivance (Lee *et al*., 2007).

6.3.1.3.2 Sugar industry

Three respondent companies in the sample represent the nine sugar mills present in the province. All but one (8 out of 9) of the participating sugar mills currently uses RFID which takes RFID adoption in the sugar mills industry to 89%. Respondents indicated that the sugar industry did consider and rejected EAS tags due to harsh operating conditions. They use RFID but only in closed-loop operations. The industry respondents also relate to a strong relationship with the ICT agency who championed RFID, confirming Rogers assertion on the role of champions.

6.3.1.3.3 Sporting Events

The sports respondent surveyed handled sporting events such as the 90 km Comrades (13 000 athletes) and the 1-Mile Midmar Mile (17 000 swimmers). It does about twenty RFID-enabled sporting events a year. It does not use EAS tags. The events company respondent use RFID at small conferences with fewer than 100 people. The respondent indicate that they have used RFID only ten times between January 2007 and May 2008.

Events have been systematically studied in this research. The result, that administrators revere an RFID solution, is not unexpected. But such events require skilled technicians, RFID engineers and software developers (Lee *et al.*, 2007). The cost will remain high as long as it remains a niche market. Diffusion, in the researchers' view, is only happening because of the considerable financial input of organisations as in the case of this respondent. Thus this will remain a niche market. Although it is very useful for other reasons like the tickets for the opening and closing ceremonies in the 2008 Olympic Games in China were embedded with RFID. This made sense as these tickets are $720 each and counterfeiting is rife in Asia (Roberti, 2008).

Will major sporting events cause the drive to RFID-enable events? The literature review indicates not. Given that RFID was used in Germany in the 2006 Soccer World Cup, it is intriguing to note that no major event has till now used RFID in South African, host of the next Soccer World Cup (2010). That this did not happen is enlightening. Many vendors tried to develop RFID tags because the carrot was huge with a possible 3 million tickets but due to a poor exchange rate, coupled with high tag costs, and human skills unavailability it simply did not persuade any taker (Thakur interviews, 2008). So FIFA, pulling the plug on RFID for 2010 has a sense of déjà vu.

6.3.1.3.4 Dairy and Cold Store Sector

There is no adoption in this business vertical in KwaZulu-Natal from the companies in the sample. The dairy in the sample is technologically advanced. As a company that espouses technology it is not surprising that it has decided to adopt RFID. However, the KwaZulu-Natal branch will only do this next year as a national roll-out is phased in. This behavior may be mimicked by many multi-national companies. This puts this dairy in the Early Majority phase.

6.3.1.3.5 Automobile Sector

RFID has total diffusion in car lock-and-key systems (100%). The automobile industry in the sample is, because of extreme competitiveness, unwilling to share IP that it has in the manufacturing plant. RFID is used in the automotive industry but only in closed-loop operations. Schmitt *et al.,* (2007) confirms this view.

6.3.2 RFID Adoption Success Factors

The research now focuses on the comparison between the perceptions of participants from adopting companies and the perception of the participants from non-adopter respondents. This will assist in answering Research Question 2, which is formulated as follows:

Research Question 2: What characteristics of companies influence the perceived adoption of RFID? To what extent do the perceptions of RFID adopters differ from the perceptions of RFID non-adopters?

The perceptions from the two categories can be analysed and summarised by the hypothesis stated below.

Hypothesis 2 *Respondents from adopting companies and respondents from non-adopting companies perceived the following factors as equally important;*

Strategic factors *Instant inventory*, *reduction in labour requirements, reduction in pickers or picking time, reduction in data captures time, elimination of some errors, lower stock-outs*, and, **RFID Experience factors** *experience,* and, **Self and Contextual Awareness** *do not know RFID well enough at this stage, to my knowledge, and, RFID is not applicable in our business,* and **Critical Success factors**
cost, human skills non-availability, implementation costs, resistance, support concerns, *RFID does not feature in my rank of priorities*, *knowledge of other RFID implementation failures*, *legislative concerns, non-availability of standards in RFID, non-availability of ICASA spectrum, privacy issues, security issues, legislative issues, other innovative solutions like 2-D barcode, barcode is good enough for our applications, time consumed to change the system, extra training for employee,* **Barcode and RFID** *RFID is a disruptive technology, RFID is better than barcode, In time, RFID will replace barcodes completely*.

Hypothesis 3: Respondents from adopting companies perceive the following factors as *more important* compared to respondents from non-adopting companies;

RFID variable *turnover, and,* **Strategic factors** *Having labour cost savings, and,* **Barcode and RFID,** *RFID ubiquity, take as long for my company to adopt RFID as it did to adopt barcode,*
RFID cost awareness

Hypothesis 4: Respondents from adopting companies perceive the following factors as *less important* compared to respondents from non-adopting companies;

Critical Success factors *technology unproven or immature, human skills non-availability, implementation costs, corporate resistance, support concerns.*

6.3.2.1 Testing Hypothesis 2

Hypothesis 2 can be broken into 28 sub-hypothesis as shown in Table 6.1. The testing of hypothesis 2 is explained in the Research Methodology Chapter, section 5.7.2. Here a hypothesis is tested and demonstrated how one arrives at the t* and the $t_{(\alpha=0.05)}$ values.

Table 6.1 Testing Parameters for sub-hypotheses for sub-hypothesis 2

Sub Hypo thesis	**Hypothesis Statement** Null Hypothesis $H_o:\mu_1=\mu_2,$ Alternate Hypothesis $H_1:\mu_1\neq\mu_2,$ Decision Accept Ho if $t^* \leq t_{(\alpha=0.05)}$	t*	$t_{(\alpha=0.05)}$	Accept Yes or No
2.1	Respondents from RFID adopting companies perceive their RFID e*xperience* as the same as respondents from the non-adopter companies.	1.1759	1.7100	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.2	Respondents from RFID adopting companies perceive *Instant inventory* as the same as respondents from the non-adopting companies.	-0.7660	1.7530	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.3	Respondents from RFID adopting companies perceive *reduction in labour requirements* as the same as respondents from the non-adopting companies.	-0.6475	1.7341	Yes, as $t^* \leq t_{(\alpha=0.05)}$

Sub Hypo thesis	**Hypothesis Statement** Null Hypothesis H_o:μ_1=μ_2, Alternate Hypothesis H_1:$\mu_1 \neq \mu_2$, Decision Accept Ho if $t^* \leq t_{(\alpha=0.05)}$	t*	$t_{(\alpha=0.05)}$	Accept Yes or No
2.4	Respondents from RFID adopting companies perceive *reduction in pickers or picking time* as the same as respondents from the non-adopting companies.	-0.1720	1.8125	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.5	Respondents from RFID adopting companies perceive *reduction in data capturer's time* as the same as respondents from the non-adopting companies.	0.1173	1.7207	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.6	Respondents from RFID adopting companies value strategic importance of e*limination of some errors* as the same as respondents from the non-adopting companies.	1.0466	1.7823	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.7	Respondents from RFID adopting companies perceive *lower stock-outs* as the same as respondents from the non-adopting companies.	0.7061	2.4444	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.8	Respondents from RFID adopting companies also *don't know RFID well enough at this stage* as the same as respondents from the non-adopting companies.	0.1427	1.7109	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.9	Respondents from RFID adopting companies view *to my knowledge; RFID is not applicable in our business* in the same way as respondents from the non-adopting companies.	-0.1966	1.7109	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.10	Respondents from RFID adopting companies view *cost* in the same way as respondents from the non-adopting companies.	-1.3900	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.11	Respondents from RFID adopting companies view *RFID does not feature on my rank of priorities* in the same way as respondents from the non-adopting companies.	0.2891	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.12	Respondents from RFID adopting companies view *knowledge of other RFID implementation failures* in the same way as respondents from the non-adopting companies.	0.1389	1.1739	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.13	Respondents from RFID adopting companies view *legislative concerns* in the same way as respondents from the non-adopting companies.	-1.1085	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$

Sub Hypo thesis	**Hypothesis Statement** Null Hypothesis $H_o: \mu_1 = \mu_2,$ Alternate Hypothesis $H_1: \mu_1 \neq \mu_2,$ Decision Accept Ho if $t^* \leq t_{(\alpha=0.05)}$	t*	$t_{(\alpha=0.05)}$	Accept Yes or No
2.14	Respondents from RFID adopting companies view *non-availability of standards in RFID* in the same way as respondents from the non-adopting companies.	-0.1985	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.15	Respondents from RFID adopting companies view *non-availability of ICASA spectrum* in the same way as respondents from the non-adopting companies.	-0.6601	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.16	Respondents from RFID adopting companies view *privacy issues* in the same way as respondents from the non-adopting companies.	-2.390	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.17	Respondents from RFID adopting companies view *security issues* in the same way as respondents from the non-adopting companies.	-2.1794	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.18	Respondents from RFID adopting companies view *legislative issues* in the same way as respondents from the non-adopting companies.	-1.4689	1.7138	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.19	Respondents from RFID adopting companies view *frequency issues* in the same way as respondents from the non-adopting companies.	1.1281	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.20	Respondents from RFID adopting companies view *other innovative solutions like 2-D barcode* in the same way as respondents from the non-adopting companies.	1.4366	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.21	Respondents from RFID adopting companies view *Barcode is good enough for our applications* in the same way as respondents from the non-adopting companies.	0.2533	1.7139	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.22	Respondents from RFID adopting companies view *Time consumed to change the system* in the same way as respondents from the non-adopting companies.	-1.2249	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.23	Respondents from RFID adopting companies view *Extra training for employee* in the same way as respondents from the non-adopting companies.	0.8950	1.7171	Yes, as $t^* \leq t_{(\alpha=0.05)}$

Sub Hypo thesis	**Hypothesis Statement** Null Hypothesis $H_o:\mu_1=\mu_2,$ Alternate Hypothesis $H_1:\mu_1\neq\mu_2,$ Decision Accept Ho if $t^* \leq t_{(\alpha=0.05)}$	t*	$t_{(\alpha=0.05)}$	Accept Yes or No
2.24	Respondents from RFID adopting companies view, *RFID represents a significant paradigm shift to our organisation* in a same manner as respondents from the non-adopting companies.	1.3000	1.7109	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.25	Respondents from RFID adopting companies view, *Lack of frequency allocation by ICASA has/will definitely impede deployment in my organisation* in the same way as respondents from the non-adopting companies.	0.6890	1.7109	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.26	Respondents from RFID adopting companies view *RFID are a disruptive technology* in the same way as respondents from the non-adopting companies.	1.0217	1.7207	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.27	Respondents from RFID adopting companies view *RFID is better than barcode* in the same way as respondents from the non-adopting companies.	1.4144	1.7531	Yes, as $t^* \leq t_{(\alpha=0.05)}$
2.28	Respondents from RFID adopting companies view *In time, RFID will replace RFID completely* in the same way as respondents from the non-adopting companies.	0.1925	1.7109	Yes, as $t^* \leq t_{(\alpha=0.05)}$

Table 6.2 summarises the central statistics for the variables perceived to be equally important for adopters and for non-adopters.

Table 6.2 Central Statistics used for hypothesis 2 testing

	Adopters			**non-adopters**		
Sub Hypothesis	n_1	**Mean (μ)**	**STD Dev (σ)**	n_2	**Mean (μ)**	**STD Dev (σ)**
2.1	11	4.45	0.934	10	4.70	0.483
2.2	11	4.45	0.934	10	4.70	0.483
2.3	11	3.73	1.104	10	4.00	0.816
2.4	11	4.36	0.505	9	4.44	1.333

	Adopters			non-adopters		
Sub Hypothesis	n_1	Mean (μ)	STD Dev (σ)	n_2	Mean (μ)	STD Dev (σ)
2.5	15	4.67	0.617	11	4.64	0.674
2.6	15	4.80	0.414	11	4.45	1.036
2.7	12	4.25	0.386	10	4.00	1.000
2.8	15	2.53	1.033	11	2.45	1.128
2.9	15	1.47	1.060	11	1.55	0.934
2.10	15	3.47	1.356	12	4.18	1.250
2.11	15	1.87	1.246	11	1.73	1.191
2.12	15	2.53	1.506	11	2.45	1.368
2.13	15	2.67	1.759	11	3.27	1.009
2.14	14	2.79	1.805	11	2.91	1.300
2.15	14	2.79	1.672	11	3.18	1.328
2.16	14	2.21	1.477	11	3.55	1.293
2.17	14	2.43	1.342	11	3.55	1.214
2.18	14	2.57	1.785	11	3.45	1.214
2.19	14	2.57	1.785	11	3.45	1.214
2.20	13	2.15	1.281	11	2.82	0.982
2.21	14	3.00	0.961	11	2.91	0.831
2.22	14	2.43	1.342	10	3.00	0.943
2.23	14	2.57	1.222	10	3.00	1.054
2.24	15	2.47	1.552	11	3.18	1.517
2.25	15	3.00	1.852	11	2.55	1.817
2.26	14	2.00	2.308	11	2.63	2.451
2.27	12	3.83	1.606	10	4.4	0.267
2.28	15	3.00	1.857	11	2.91	1.091

6.3.2.2 Testing Hypothesis 3

Table 6.3 presents the sub-hypothesis number (Column 1), the actual hypothesis the computed t* (Column 2) and the t-test table look up value (Column 3). Note that as $t^* \geq t_{(\alpha=0.05)}$ we reject H_o and we accept H_1 that the means of the adopters are greater than the means of the non-adopters. The sub-hypothesis number is also used as an index for central statistics for each variable is given in Table 6.4.

Table 6.3 Testing parameters for Hypothesis 3

Sub hypo-thesis	**Hypothesis Statement** Null Hypothesis H_o:μ_1=μ_2, Alternate Hypothesis H_1:μ_1-$\mu_2 \geq$ **x** Decision Reject Ho if $t^* \geq t_{(\alpha=0.05)}$ and accept H_1	t*	$t_{(\alpha=0.05)}$	As, $t^* \geq t_{(\alpha=0.05)}$. Reject H_o Accept H_1
3.1	Respondents from RFID adopting companies perceive *turnover* as *more important* compared to respondents from non-adopting companies.	1.7402	0.0499	d=154 Yes, as $t^* \geq t_{(\alpha=0.05)}$
3.2	Respondents from RFID adopting companies perceive *labour cost savings* as *more important* compared to respondents from non-adopting companies.	1.7732	0.0498	d=0.13 5 Yes, as $t^* \geq t_{(\alpha=0.05)}$
3.3	Respondents from RFID adopting companies perceive *RFID will be as omnipresent (ubiquitous) as barcode* as *more important* compared to respondents from non-adopting companies.	1.7186	0.0496	d=0.01 Yes, as $t^* \geq t_{(\alpha=0.05)}$
3.4	Respondents from RFID adopting companies perceive *take as long for my company to adopt RFID as it did to adopt barcode* as *more important* compared to respondents from non-adopting companies.	3.348	0.4967	d=0.13 Yes, as $t^* \geq t_{(\alpha=0.05)}$
3.5	Respondents from RFID adopting companies perceive *keenly aware of costs associated with RFID* as *more important* compared to respondents from non-adopting companies.	1.7748	1.7709	d=0.39 Yes, as $t^* \geq t_{(\alpha=0.05)}$

Table 6.4 summarises the central statistics for the variables perceived to be equally important for adopters as for non-adopters.

Table 6.4 Central Statistics used by hypothesis

	Adopters			**non-adopters**		
Sub Hypothesis	**n_1**	**Mean (μ)**	**STD Dev (σ)**	**n_2**	**Mean (μ)**	**STD Dev (σ)**
3.1	14	2028.09	7604286.17	14	495.79	1177610.80
3.2	14	4.50	0.5690	11	3.36	3.0545
3.3	15	4.07	0.9238	11	3.45	0.6727

	Adopters			non-adopters		
Sub Hypothesis	**n_1**	**Mean (μ)**	**STD Dev (σ)**	**n_2**	**Mean (μ)**	**STD Dev (σ)**
3.4	15	2.40	2.400	10	4.20	1.2889
3.5	15	4.13	0.2667	11	3.09	1.2910

6.3.2.3 Testing Hypothesis 4

Table 6.5 presents the sub-hypothesis number, the actual hypothesis the computed t* and the t-test table look up value for α=0.05. Note that as $t^* \geq t_{(\alpha=0.05)}$ we cannot reject H_o which is why we accept that the means are equal for all values in this table. The sub-hypothesis number is also used as an index for central statistics for each variable is given in the Table 6.6.

Table 6.5 Testing parameters sub-hypothesis for hypothesis 4

Sub-Hypothesis	**Hypothesis Statement** Null Hypothesis H_o:μ_1=$\mu_{2,}$ Alternate Hypothesis H_1: $\mu_2 - \mu_1 \geq$ **d**. Decision Reject Ho if $t^* \geq t_{(\alpha=0.05)}$ and accept H_1	t*	$t_{(\alpha=0.05)}$	Yes, as $t^* \geq t_{(\alpha=0.05)}$
4.1	Respondents from RFID non-adopting companies perceive *technology unproven or immature* as *more important* compared to respondents from adopting companies.	1.7237	1.7138	d=0.37 Yes, as $t^* \geq t_{(\alpha=0.05)}$
4.2	Respondents from RFID non-adopting companies perceive *Human skills non-availability* as *more important* compared to respondents from adopting companies.	1.7246	1.7171	d=0.51 Yes, as $t^* \geq t_{(\alpha=0.05)}$
4.3	Respondents from RFID non-adopting companies perceive *Implementation costs* as *more important* compared to respondents from adopting companies.	1.7281	1.7109	d=0.6 Yes, as $t^* \geq t_{(\alpha=0.05)}$
4.4	Respondents from RFID non-adopting companies perceive *Corporate resistance* as *more important* compared to respondents from adopting companies.	1.7500	1.7291	d=0.33 Yes, as $t^* \geq t_{(\alpha=0.05)}$

Sub-Hypothesis	**Hypothesis Statement** Null Hypothesis H_o:μ_1=$\mu_{2,}$ Alternate Hypothesis H_1: $\mu_2 - \mu_1 \geq$ **d**. Decision Reject Ho if $t^* \geq t_{(\alpha=0.05)}$ and accept H_1	t*	$t_{(\alpha=0.05)}$	Yes, as $t^* \geq t_{(\alpha=0.05)}$
4.5	Respondents from RFID non-adopting companies perceive *Support Concerns* as *more important* compared to respondents from adopting companies.	1.7292	1.7109	d=0.48 Yes, as $t^* \geq t_{(\alpha=0.05)}$

Table 6.6 summarises the central statistics for the variables perceived more important for non-adopters than for adopters.

Table 6.6 Central Statistics used by hypothesis 4 testing.

	Adopters			Non-adopters		
Sub Hypothesis	**n_1**	**Mean (μ)**	**STD Dev (σ)**	**n_2**	**Mean (μ)**	**STD Dev (σ)**
4.1	15	2.6667	1.8095	11	3.9091	1.4909
4.2	15	2.5333	2.8381	11	3.9091	0.6909
4.3	15	3.1333	1.6952	11	4.4545	0.6727
4.4	15	2.6667	2.8095	11	3.8181	0.3636
4.5	15	2.4000	2.8286	11	3.8181	1.1636

6.4 Conclusion

The overarching impression is that RFID adoption is taking place in KwaZulu-Natal and that this innovation is prevalent in certain specific verticals and even here in certain niche markets such as lock-and-key systems for automobiles and to track athletes.

The results of this research indicate that the current diffusion rate in KwaZulu-Natal is estimated at 19% ± 3. The results also show that RFID adoption follows different patterns according to different business verticals. The sugar industry has almost total adoption of RFID, the library has full adoption, albeit of another form of Auto-ID, the Dairy Sector has no adoption and the automobile sector has full diffusion for lock-and-key systems and full diffusion of closed-loop RFID systems.

This is the surprise result in that RFID is being used in the sample always in closed loops - the value of information sharing in Supply Chain Management is either being deliberately ignored due to a strategic advantage, or, the reuse nature of the tags in closed loop makes this the only way to justify RFID given the cost. This may well explain why RFID is not getting faster adoption.

There are certain perceptions about RFID that are viewed similarly by both the adopter and the non-adopter categories (Hypothesis 2). This turned to be the majority of the factors (Table 6.1) such as privacy, frequency issues, legislative issues, etc.

On the other hand, there are certain factors which are perceived more strongly by adopters than by non-adopters (Hypothesis 3). Examples of these are turnover and labour cost savings (Table 6.3).

Finally, there are certain factors which are perceived more strongly by non-adopters than by adopters (Hypothesis 4). Examples of these are Humans Skills non-availability and implementation costs (Table 6.5).

The next chapter examines these results and produces recommendations. In addition, the last research question three, "*How do decision makers perceive the attributes of the RFID innovations,"* requires a little synthesis from the results and is also presented.

Chapter Seven
Recommendations and Conclusion

7.1 Introduction

In this chapter the results of the research are summarised and compared with similar work from the reviewed literature with the view of establishing the scientific contribution of this effort to the body of knowledge in the field of RFID adoption. The results are synthesised or interpreted into pragmatic recommendations that may be used.

7.2 RFID Diffusion Rate

This research shows that the diffusion rate is just located over the chasm (19 ± 3%) on the technology adoption curve for the research population.

Comparison with existing literature

This is the single *most important contribution* of this research as there is no other equivalent empirical research found.

To the researchers' knowledge there has been no similar effort to predict *where* RFID diffusion is on the Technology Adoption curve. Perhaps this is because most diffusion studies have been *post facto*, that is, after the technology has ceased. There was no paper found that predicted what percentage of the industry is using RFID. Peng (2004) undertook similar research, albeit with the adoption of a different technology: Linux. He also used a different statistical model, the Bayesian Model, and he found that Linux adoption is in the Early Majority phase.

It is difficult to predict at which stage an adoption is in under any circumstances (Peng, 2004). However, Rogers (1995), Moore (1999), Norman (1998) and Von Hippel (2005) provide sufficient literature and structured analysis to support this research effort. Indeed Moore's work is widely adopted by mainstream technology companies to make an educated guess or "see" where their product is in the technology adoption lifecycle. So this study's use of Moore is with precedent.

Recommendation

Moore (1999) studied many cases and determined the chasm to be a point beyond which it is "safe" to adopt a new technology as it *will* become mainstream technology. This implies a continuity of the product, thereby implying on-going support and service availability. Based on the fact that this research has approximated the adoption rate to be just beyond the chasm, one may confidently recommend that RFID be seriously considered for early majority adoption.

This means that if a company considers its characteristics to be an "early majority" adopter of technologies then making the decision to adopt is prudent. If, however, a company perceives itself more of a late majority type of organisation, then a pilot or 'RFID proofing' at the very least is the recommended appropriate action to pursue for now. This certainly implies that ignorance is no longer an option, so companies that do not know of RFID or have not heard of RFID, should commit to RFID familiarisation process.

7.3 RFID adoption per business vertical

The results show that RFID adoption differs from one business vertical to another.

Comparison with existing literature

Rogers calls a business vertical a communication channel, and determined that as soon as one member in a channel adopts an innovation, the others in the same grouping gain knowledge and may be influenced (Rogers, 1995). It also helps adoption when a big player picks the "tab" like Wal-Mart volunteered to do so (Cavoukian, 2004). The sugar industry adopted, as it is the reasons were: a combination of a business the need for independent verification, security, *and* the influence of a champion. The dairy (currently, zero adoption) *will* adopt as indicted because reasons its head office has indicate a willingness to handle the technology issues, and the head office has a proven history of supporting. This takes away the fear of "new or unproven technology" in technological projects.

Recommendation

Companies that are fiscally able should adopt, perhaps, initially through a pilot. In addition to talking to vendors, it will be useful for a company to independently study and determine the impact of RFID in their respective vertical; in the local region and, country and the world. The sector study conducted shows that the rate of adoption differs from one vertical to another. In other words, certain verticals are more likely to adopt than others. Jahner (2008) conducted a multi-sector study of 463 respondents and found diffusion poor in general.

The dynamics of industry and the interaction between competitors vary from vertical to vertical. Indeed Sarma (2005) supports the view that in certain industries there may be opportunities for competition and cooperation to co-exist. This is termed coopertition. *Coopertition* is where innovations are shared by competitors for the mutual benefit of the industry. This is an area of opportunity for the use of RFID and even a possible future research area. One may even consider an industry-led vertical pilot. Mortensen and Pedersen (2004) reported on in such pilot in construction and logistics pilot.

7.4 Research Adoption Perceived Success Factors: Research Hypothesis Two

This addresses **Research Hypothesis Two**: The size of the company, the nature of its business and its strategic vision influence its RFID adoption decision.

7.4.1 Turnover

The turnover for adopters is higher for adopters than non-adopters.

Comparison with existing literature

This is an interesting result as it validates Rogers' generalisations which predict that the size of the company impacts its ability to adopt innovations. Size was the characteristic of choice to describe a company in this study. This result is in line with Knebel *et al.* (2007) who found a positive correlation between adoption and size. The novelty here is that size in this research is turnover, which is different from other comparative studies which use number (number of employees, number of branches and other factors. Turnover was the factor chosen in the sample to represent the organisational factor, namely, size. Indeed, it turned out that adopters have a larger turnover than non-adopters. Most studies surveyed use the number of employees as an indication of size.

This is reasonable as large companies are more able to absorb the cost (and the risk) of an RFID project. The studies in this thesis bear testimony to this: in retail the top five largest companies in the world from, Wal-Mart to Metro, all use RFID to varying degrees. In South Africa, the largest retail companies, Pick ’n Pay and Spar, are busy with RFID pilots. The US DOD uses RFID as well as the largest motor manufacturing motor (Schmitt, 2007) companies in the world use RFID. With agriculture in South Africa, RFID is used in the three largest sectors: Wine, Forestry and Sugar segments. A business vertical analysis is undertaken next.

Recommendation

Companies in the supply chain should look towards the largest member of their respective chain to determine the direction they are heading with RFID. This will significantly reduce the barrier to entry.

Pohoresky (2003) conducted a similar, though far less intense, exercise and simply asked if a factor would (i) affect adoption decision (+) or (ii) would not affect adoption decision (-) as depicted in Table 4.1. Brown and Russell (2007) also undertook a survey in South Africa, but their sample had non-adopters. This study goes further and compares the extent of perceptions of adopters and non-adopters on factors. The vast number of factors makes analysis onerous especially to readers who have particular biase.

7.4.2 Experience

This research shows that each of the adopters have staff with several years of RFID experience, with more than 73% of the respondents boasting experience of four years or more.

Comparison with existing literature

That both categories have equal means is an unexpected result as 14 of the respondents are non-adopters. It may be that non-adopters companies have experienced staff awaiting eventual RFID deployment. This may even show that companies are gearing themselves for RFID. Indeed Brown and Russell (2007) conclude that companies are “future-proofing themselves for the eventual adoption of RFID.” This is the recommendations of researchers like Kumar (2004) and Plaggenborg (2006).

Recommendation

Given that *human skills unavailability* is a key result the availability of experience is crucial factor. The presence of such competent staff mean that even if no adoption currently takes place it is still prudent to consider eventual RFID adoption as you make process changes in the organisation to "future-proof your organisation (Brown and Russell, 2007)."

7.4.3 Strategic factors

For strategic variables this result is expected as both adopters and nod-adopters still require a strategic advantage for the following factors: inventory, lower stock-outs, less shrinkage, elimination of some errors, and, less theft

Comparison with existing literature

Hardgraves (2006) undertook the largest case study on the impact of RFID on strategic variables like stock outs. He studied the variables inventory, lower stock-outs, less shrinkage, elimination of some errors, and, less theft. This was a very large study that comprised Wal-Mart stores. The South African sample respondents equally crave these variables, among others. Moorgas (2007) and Brown and Russell (2007) also had similar experience with South African customers. This experience is much like the Italian experience who favour reducing stock-outs and inventory inconsistencies.

Recommendation

It is reported elsewhere that the biggest two South African retailers are conducting pilots in RFID, other similar stores, even smaller ones must attempt to learn about this experience.

7.4.4 Cost

Both set of respondents agree that RFID is expensive.

Comparison with existing literature

The attitude of non-adopters towards *cost* is surprising. The researcher expected non-adopters to have more of an issue with cost than adopters. This is not unique to the developing countries, like South Africa, as China executives are also concerned about cost as well

(Hutchinson and Zhang, 2005). Yet China boasts the world's largest RFID project (Harrop, 2008). This contradiction is a graphic illustration of the thin line separating proponents and opponents, as there is not one market where all vested parties, supports RFID unambiguously. There is also evidence, that sample adopters are high turnover companies to whom cost may not be an issue (Knebel *at al.*, 2007).

Certainly feels the RFID cost Roberti (2007) is coming down in he's now seminal article "the 5c tag." So companies need to move beyond this perception and consider "when" rather than "if" they adopt.

7.4.5 Security, privacy and legislative issues

Both set of respondents have similar views on privacy, security, and legislative issues. The surprise is that both sets of respondents have very neutral views on the variables (Factors 2.16, 2.17 and 2.18) in Table 6.2.

The "neutral views" of both categories with respect to Security, Privacy and Legislative issues is interesting. Kumar (2004) and others also report that Western countries are far more likely to be sensitive about privacy issues. Perhaps, this may be the reason why South Africa, as a developing country, focuses more on the opportunity than the legal issues. Most governments and regions mentioned in this study Canada, Germany, Italy, South Africa, Botswana, Australia, Hong Kong and the European Commission, US government have a RFID policy or about to implement one. The impact of RFID will be global, so adopting a technology that is the incorrect frequency will automatically exclude a particular market (Kumar, 2004).

Recommendations

Companies *must* align their policies to include RFID security, RFID privacy and RFID legislative issues in the implementation phase. Simply ignoring these issues will postpone the cost because governmental policy *will* evolve into legislation (Bitko, 2006). Further, a post implementation reconfiguration will increase costs.

7.4.6 Barcode and RFID

RFID is a disruptive technology, RFID is better than barcode, in time, RFID will replace barcodes completely. Both set of respondents agree that, RFID is disruptive, that, RFID is better than barcode, and, that in time RFID will replace barcodes.

Comparison with existing literature

Almost all literature reviewed agree with Sarma (2005) that RFID will fundamentally change the business process. It is therefore not unexpected that both groups agree with this assessment. Most pro-RFID researchers (Kumar, 2004), Sarma (2005), Weis (2003) agree that RFID is disruptive, that, that RFID is better than barcode, and, that in time RFID will replace barcodes.

Recommendations

These are perception on future variables and it is interesting that the belief is that RFID will prevail. Companies must take cognisance of this view.

7.4.7 General Factors

Strategic factors reduction labour requirements, reduction in pickers or picking time, reduction in data capture time, labour cost savings, **Contextual awareness of RFID** Don't know RFID well enough at this stage *and* To my knowledge, RFID is not applicable in our business (Factors 2.8 & 2.9 in Table 6.2.and Table 6.3).

Respondents from both group concurred with each other and were “neutral” on this issue.

Comparison with existing literature

This is an intriguing set of results as it shows that there is a convergence of views of many factors on many levels. It must be remembered that this is a comparison of the means of two populations; it does not say anything about the scale of the factors. This is covered in Table 6.3.

Recommendation

The researcher recommends that companies who consider RFID undertake a pilot or a “proof-of-concept” this will test perceptions against the technical capabilities of the vendor products.

7.4.8 Labour cost savings

Adopters see labour cost savings as being more important than non-adopters.

This is an issue in all analysis, the issue being not to replace humans because of cost only but to replace human to automate and for speed and reduced errors. This is an issue that has serious consequence in a developing country like South Africa where labour union activism is strong.

Recommendation

It is therefore recommended that RFID be "sold" as a technology that improves life-like the case reporting a miner's life being saved, like tracking kids in a theme park, etc.

7.4.9 RFID (ubiquity): it will take as long to adopt RFID as it did barcode.

Recommendation

The barrier for adoption can be huge - it requires imaginative, creative marketing to persuade takers. For example, as already reported in this study, barcode gained faster acceptance by users when adopting companies promised to refund the full amount if a barcode scan was proven incorrect (Personnel Interviews, 2008). Similarly Wal-Mart's gesture to fit the bill for RFID implementation was met with complicity by its trading partners. Forcing trader's partners to do something can create pockets of resistance which sometimes serve only to retard diffusion of this technology.

7.4.10 Factors: Means for non-adopters are greater than the means of adopters

Research results indicate that the following factors are perceived to be more of a barrier for RFID non-adopters than they are for RFID adopters:

Critical Success factors Technology unproven or immature, Human skills non-availability, Implementation costs, corporate resistance, Support Concerns.

This shows that RFID adopters are in general satisfied with RFID implementation. For non-adopters the story is more about implementation, integration, cost and immaturity. These are understandable and valid concerns. Certainly these factors find support from *Hutchinson and Zang* (2005) who found that cost, untested market and integration issues to be significant variables in China. Koh *et al.* (2006) had a similar result and found lack of technical expertise which the study calls Human skills non-availability and uncertainty of the technology (unproven or immature technology) as issues.

Recommendation

The argument has already been presented in 7.2.1 that we *have* crossed the chasm and therefore the insecurity alluded by the above listed factors should no longer be the case. Consequently, it is recommended that more awareness be raised to redress the perception of these factors. It is important that a rational and realistic view of RFID be propagated. The success of RFID in ICT will only happen with the dissemination of vendor neutral, technology agnostic studies such as this.

CompTIA, the industry training vendor, has already released a vendor certification called RFID+ (RFID+ Certification, 2006) to help with RFID so this is an indication of an industrial response over *Support Concerns.*

7.5 Decision makers' perception of the attributes of RFID innovation?

Rogers and several others consistently found that the main attributes in determining the success of any innovation in general are: relative advantage, compatibility, complexity, observability, and trialability**.** It is fitting that Schmidt *et al*. (2007) validated that in the particular context of RFID adoption these variables also hold. Other researchers (Brown and Russells (2007) and Pohoresky(2004) also went straight to Rogers to examine these variables.

7.5.1 Relative Advantage

Relative Advantage is the degree to which an innovation is perceived as being better than the idea that it supersedes according to economic profitability, prestige etc. Pohoresky (2003) determined that the following factors are relevant for Relative Advantage:

Factors that Positively (+) Influence adoption *No line of sight required, Increased read range from barcodes, Unique identity for each unit, Greater capacity of information, Durability against hazards, Accurate readings, Theft or counterfeit protection, Proven results with Automatic ID.*

Factors that Negatively (-) influence adoption *Cost of tag, Cost of reader, Cost of Infrastructure* (database storage, software, implementation, integration, consulting services, and change management).

For (+) influence, there is agreement between the results and Pohoresky (2003). The reader is invited to consult Table 6.2 and Table 6.3 for these variables. The results show both groups strongly agreed that *cost* is a barrier to adoption (means 3.47 and 4.18). In addition the non-adopter group thought that implementation costs were more of a barrier than adopters.

7.5.2 Compatibility

Compatibility is the degree to which a technology is perceived to be consistent with an organisation's strategic intent, infrastructure, practice and needs. Pohoresky(2003) determined the following factors are relevant for Compatibility:

Factors that Negatively (-) influence adoption *Frequency, tag, reader standards, International compatibility, Change management, Privacy concerns at item level tagging.*

Surprisingly, the adopter and non-adopter categories concurred and were "neutral" about the following issues: *standards* (Factor 2.14 in Table 6.5 and 6.6), *Privacy concerns* (Factor 2.16 in Table 6.5 and 6.6), and *Frequency* (Factor 2.19 in Table 6.5 and 6.6).

Here the results differed from Pohoresky, as for the variables *Change management. Technology unproven or immature* (Factor 4.1 in Table 6.5 and 6.6) is a factor which non-adopters view as a bigger barrier.

7.5.3 Complexity

Complexity is the degree at which something is perceived as being difficult to use. Pohoresky (2003) determined the following factors are relevant for complexity: negatively (-) influence adoption ERP and software integration, Reader collision, Read range limitations.

There is already evidence to support this as the results show non-adopters *implementation costs* (Factor 4.6 in Table 6.5 and 6.6) were more of a barrier than adopters. This study has delimited discussion on technical issues but it is useful to note that there is ongoing research in this. *Technology unproven or immature* (Factor 4.1 in Table 6.5 and 6.6) is also another factor which non-adopters view as a bigger barrier.

7.5.4 Observability

Observability is the degree to which the results of innovations are visible to others. Pohoresky (2003) determined the following factor is relevant for observability which positively (+) influence adoption: *ROI measurement capability.*
There is already evidence to support this as *keenly aware of costs associated with RFID* as *more important* is a view more strongly shared by adopters than non-adopters (Factor 3.5 in Table 6.3 and 6.4).

The knowledge of members using RFID varies from vertical to vertical. One sample case did not know that they were using RFID. This is not unusual, as they had a functional knowledge of the system, not of RFID. The automotive cluster uses RFID in close loop operations but refuse to say how (Thakur Interviews, 2008). The more general rule is that as RFID diffuses in one vertical the other members begin adopting as well, as the Sugar case demonstrates.

7.5.5 Trialability

Trialability allows innovations to be tried out before possible adoption. Pohoresky (2003) determined the following factor is relevant for Trialability which positively (+) influence adoption: *Pilot capability.* Of the thirty respondents in the sample, *all* are aware of RFID implementations. From Figure 6.2 one may conclude that 17.3% used RFID.

7.6 General Recommendation

Tables A.1 to A.6 depict the central statistics to each question in the questionnaire. These values also provide a very easy and meaningful perspective on the factors. Also for a particular company certain variables have more relevance, so a study of these tables will be meaningful.

Current adopters appear to be high turnover organisations, it is recommended that these “big players” pull other players towards adoption, not necessarily because they share a common vision such as reducing labour costs, but because they share the same business space where the RFID tag can be a medium for communication. Just like the telephone, the true benefit of RFID will only be realized if strategic partners adopt.

In addition, it is recommended that non-adopters undertake RFID pilots in order to accumulate the relevant experience so as to be ready when RFID is ubiquitous**.**

For organisations, RFID is a double edged sword and a multifaceted diffusion problem:

- *Procrastinate*, and the organisations may have to adopt RFID when they are pulled by suppliers, by customers or by legislation.
- *Adopt*, and the organisations stand alone but with opportunity, knowledge and the economic burden.

A fitting final recommendation will be that perhaps the answer is somewhere between the two. Adopt piece-meal where value is apparent, opportunity possible and intelligence collectable. Adoption and diffusion are both processes in their own right. RFID has profound implications on security, on privacy, on bandwidth and on processing.

It is therefore recommended that companies consider a pilot that involves a closed-loop operation. This will allow for the reuse and the recycle of tags, the test the applicability of RFID to a particular work segment, and allow for technology to prove itself, develop human skills and lower the implementation costs.

7.7 Future Work

7.8 Conclusion

This chapter presented the results along with some recommendations.

It first showed that this research found that the diffusion rate is just located over the chasm (19 ± 3%) on the technology adoption curve for the research population.

It then showed that turnover does influence the innovativeness of an organisation as high turnover companies are more likely to adopt. This validates Rogers' assertion that size does influence adoption.

The questionnaire had many factors which were broken down into sections where the means for both adopting and non-adopting groups were the same, where the means of the adopting group is greater than the non-adopting groups, and finally, where the means of the adopting group is less than the non-adopting groups.

It then presents a section on how decision makers assess attributes of the RFID innovation, such as relative advantage, compatibility, complexity, observability, and trialability.

It finally suggests that companies that have not adopted RFID at the very least conduct a pilot in RFID.

It also shows that RFID has excellent adoption rates in certain niche markets and in some verticals like the automobile industry. On the other hand, it has shown no adoption where logic dictates where it should already be adopted, like the cold chain.

RFID is, clearly, a technology that has the potential to become a disruptive technology.

Appendix One (RFID Questionnaire)

The Nature, extent and impact of RFID adoption

THE NATURE, EXTENT AND IMPACT OF RFID ADOPTION

This is a survey on RFID and its adoption or non-adoption.

South Africa is the world's *fourth largest net importer* of technology. This dubious distinction does not reflect in the adoption of RFID. The perceived slow rate of RFID adoption in the South African market in this context is therefore telling. On the other hand many companies have either piloted an RFID project, adopted RFID or have decided on a time frame to adopt RFID.

There must be some reasons driving this perceived slow adoption. This study aims to identify *who* is using RFID, *where* they are using it, and examines their experiences. This study is opportune, timely and relevant given the infancy of RFID.

This study further aims to determine the adoption rate (diffusion) by finding out where (and how) RFID is deployed. It also evaluates where (and why) it has met with less success or was not deployed. In doing this it also attempts to analyse experiences of RFID pilots and corresponding reasons for adoption or non-adoption.

This is crucial as many companies face demanding capital investment decisions that may involve RFID deployments in the near future. This study assesses the risk and attempts to find the critical success factors that influence this decision. It examines the current adopters (and non-adopters) and attempts to quantify the nature and extent of RFID adoption.

Participation is entirely voluntary and requires the completion of this questionnaire.

Confidentiality
All data will be treated confidentially and will only be used for this research study. No individual information will be released to any vendor or third party.

Please contact Mr Surendra Thakur at thakur@dut.ac.za or Cell +27 083 787 6991 with questions, suggestions or further information requests.

Kind Regards

Surendra Thakur	**Prof Eyono Obono**
________________	________________
Researcher	**Thesis Supervisor**

A. ORGANISATIONAL PROFILE

1) Please fill in the following details?	
Name	
Web address	
Company Age	
Listed? Y/N	
Multi-National Presence (Name Continents)	
National Presence (Name Provinces)	
Vertical (e.g. Auto, retail)	
Market-share held	
Number Staff	
Company Turnover	
Company Activities	

B. PARTICIPANT PROFILE

2) Kindly quantify the experience you have with RFID technology?

>= 6 yrs	5-6 yrs	4-5 yrs	3-4 yrs	2-3 yrs	1-2 yrs	0-1yrs	0

3) How long have you been reading about, learning and generally following RFID?

>= 6 yrs	5-6 yrs	4-5 yrs	3-4 yrs	2-3 yrs	1-2 yrs	0-1yrs	0

4) I have been to ----X--- RFID workshops in 200x. ?

X=	X=	X=	X=	X=	X=	X=	X=	X=
2000	2001	2002	2003	2004	2005	2006	2007	2008

5) My job description? Tick or fill in:

Operational Management	Strategic Management	Executive Management	Non-Manager

6) Please name two local vendors/manufacturers/integrators in RFID that you are aware of**?**

7) My role in the company with respect to RFID involves:

8) Please indicate the passive RF operating frequency in RSA?

C. RFID ADOPTION

9) Please respond Yes or No	Yes	No	N/A
We have conducted a pilot which was merely to accumulate intelligence and business experience			
After pilot, RFID will be implemented			
No Pilot, but RFID will be implemented			
RFID application already implemented			
Number of Personnel involved (Pilot or Implementation)			
Man hours in Project (Pilot or Implementation)			
Value of Project in ZAR (Pilot or Implementation)			

10) Which of the following appeal to you or your organisation?	Not at all		To some Extent	To a large extent	
	1	2	3	4	5
Instant inventory					
Reduction in labour requirements especially unskilled staff					
Reduction in pickers or picking time because of automated location					
Reduction in data capture time					
Elimination of some errors					
Labour cost savings					
Lower stock-outs					
Less shrinkage					
Less theft					

11) For each of the following select what applies.			
	Yes	No	N/A
My organisation's technical/hardware employees have been to RFID training			
My organisation's programmers have been to RFID training			

12) For each of the following indicate where, in your opinion, data generated by RFID will benefit your organisation or adopters.

	Yes	No	N/A
Demand management			
Customer tracking in store			
Product tracking outside the store			
Retail promotion management			
Customer loyalty programs			
Inventory management			
Production visibility (raw material receipt, WIP tracking, FG tracing)			
Transportation/logistics/supply chain optimization			
Safe and secure supply chain (reverse logistics, expiration data management)			
Planning, forecasting, coordination etc in Supply chain			
Shrinkage control			
Other			

13) Which of the following appeal to you or your organisation?	**Not at all**	**To some Extent**		**To a large extent**	
	1	2	3	4	5
Adoption of new technology, like RFID by my organisation is a huge policy decision given the business risk					
RFID represents a significant paradigm shift to our organisation					
Privacy issues is (or will be) a serious challenge to RFID deployment in my organisation					
Security issues has been or will be a challenge to RFID deploy-ment in my organisation					
Lack of frequency allocation by ICASA has/will definitely impede deployment in my organisation					

14) RFID AND BARCODE Rank the following:	**Not at all**	**To some Extent**		**To a large extent**	
	1	2	3	4	5
RFID is a disruptive technology					
RFID is better then barcode					
RFID will be as omnipresent (ubiquitous) as barcode					
It will/has taken take as long for my company previous to adopt RFID as it did to a switch to barcode in the 80's					
I am aware of the costs associated with barcodes					
In time, RFID will replace					

barcodes completely					

D. ORGANISATIONAL AND ENVIRONMENT

15) To my knowledge, the following members of my vertical are using RFID?	To some Extent				To a large extent
Member	1	2	3	4	5

16) Which of the following appeal to you or your organisation?	Not at all		To some Extent		To a large extent
	1	2	3	4	5
Customer's satisfaction					
Supplier requirement Eg DOD, Wal-Mart					
Higher sales					
Higher customer service					
Better retailer promotions					
Better manufacturer promotions					
Better new product introductions					
Lower total cost of ownership					

17) For each of the following select what applies?			
	Yes	No	N/A
I am aware of RFID training organisations			
There are skills in RFID or expertise in my organisation to drive an RFID project			
My software vendor(s) is prepared to develop programs for me (using RFID)			

18) Which of the following according to you is a barrier?	**Not at all**		**To some Extent**		**To a large extent**
	1	2	3	4	5
Don't know RFID well enough at this stage					
To my knowledge, RFID is not applicable in our business					
Cost					
Technology unproven or immature					
Human skills non-availability					
Implementation costs					
Corporate resistance					
Support concerns					
RFID does not feature on my rank of priorities					
Knowledge of other RFID implementation failures					
Legislative Concerns					
Non-availability of standards in RFID					
Non-availability of ICASA spectrum					
Privacy Issues					
Security Issues					
Legislative Issues					
Frequency Issues					
Other innovative solutions like 2-D barcode					
Barcode is good enough for our applications					
Our current app is good enough					
Time consumed to change the system					
Extra training for employee					

19) RFID has had /will have a massive impact on?(Rank 1-6 in order of importance)	
Sales	☐
Marketing	☐
Supply Chain Management	☐
Inventory or Stock Management	☐
Asset Management	☐
People/Livestock Monitors	☐

20) Data generated by the RFID systems is/will be stored at:	
Retailer	☐
Manufacturer	☐
Supply chain partners	☐

21)At what level of granularity will RFID (has been) / (be) implemented within the next 3 years?	
Not at all	☐
Pallet	☐
Box	☐
Item	☐
Don't know/not applicable	☐

22) The cost RFID deployment tags in my organisation is/will be borne by?	
Suppliers	☐
Manufacturers	☐
Logistics service provider	☐
My Organisation	☐
Shared by SCM	☐
Don't know/ not applicable	☐

E. RFID ADOPTION PROCESS

23)The following refers to the adoption process. Please indicate your best recollections to the questions that follow. Use the next page or email the researcher if you have any queries.	
Which of the following did you discuss RFID with to arrive at your decision	Please indicate an name (if possible)
My Software vendor	
An local associate in my vertical or competitor	
Professional organisation	
An international associate in my vertical or competitor	
Supplier	
Customer	

F. COMMENTS, CRITICISM, SUGGESTIONS

24) Please write down your comments here.

Appendix Two (Central Statistics for the RFID Questionnaire)

This appendix has the descriptive statistics of the variables that we discuss primarily in Chapter Six. The data is used to answer some research questions poised.

The following Table A.1 summaries the descriptive statistics for Question 10 "Which of the following appeal to you or your organisation?"

Table A. 1 Which of the following appeals to you or your organisation?

Question 10	**Adopters**			**Non-adopters**		
Which of the following appeal to you or your organisation?	**N**	**Mean (μ)**	**STD Dev (σ)**	**N**	**Mean (μ)**	**STD Dev (σ)**
Instant inventory	11	4.45	0.934	10	4.70	0.483
Reduction in labour requirements	11	3.73	1.104	10	4.00	0.816
Reduction in pickers or picking time	11	4.36	0.505	9	4.44	1.333
Reduction in data captures time	15	4.67	0.617	11	4.64	0.674
Elimination of some errors	15	4.80	0.414	11	4.45	1.036
Labour cost savings	14	4.50	0.760	11	3.36	1.748
Lower stock-outs	12	4.25	0.622	10	4.00	0.943
Less theft	10	4.60	0.516	10	4.50	1.080

The following Table A.2 summaries the descriptive statistics for Question 12 "For each of the following indicate where, in your opinion, RFID will benefit your organisation or adopters?"

Table A.2 For each of the following indicate where, in your opinion, RFID will benefit my organisation or adopters?

Question 12 (N=30) *For each of the following indicate where, in your opinion, RFID will benefit my organisation or adopters?*	Agree	The variables on the left have been ranked as a number of respondents
Shrinkage control	23	The high number for shrinkage is interesting as this implies that RFID can reduce this measure
Transportation/logistics/supply chain optimization	20	
Production visibility (raw material receipt, WIP tracking, FG tracing)	19	It would appear that RFID is more useful in supply chain and safe and secure supply chain, production planning and forecasting
Inventory management	19	
Planning, forecasting, coordination etc in Supply chain	18	
Safe and secure supply chain	18	

The following Table A.3 summaries the descriptive statistics for Question 18 "Which of the following is a barrier according to you?"

Table A.3 Which of the following is a barrier according to you?

Question 18	**Adopters**			**Non-adopters**		
Which of the following is a barrier according to you?	N	**MEAN (μ)**	**STD DEV (σ)**	**N**	**MEAN (μ)**	**STD DEV (σ)**
Don't know RFID well enough at this stage	15	1.73	1.033	11	2.45	1.128
To my knowledge, RFID is not applicable in our business	15	1.47	1.060	11	1.55	0.934
Cost	15	3.47	1.356	12	4.18	1.250
Technology unproven or immature	15	2.67	1.345	11	3.91	1.221
Human skills non-availability	15	2.53	1.685	11	3.91	0.831
Implementation costs	15	3.13	1.302	11	4.45	0.820
Corporate resistance	15	2.67	1.676	11	3.82	0.603
Support concerns	15	2.40	1.682	11	3.82	1.079
RFID does not feature on my rank	15	1.87	1.246	11	1.73	1.191

Question 18	**Adopters**			**Non-adopters**		
Which of the following is a barrier according to you?	N	**MEAN (µ)**	**STD DEV (σ)**	**N**	**MEAN (µ)**	**STD DEV (σ)**
of priorities						
Knowledge of other RFID implementation failures	15	2.53	1.506	11	2.45	1.368
Legislative Concerns	15	2.67	1.759	11	3.27	1.009
Non-availability of standards in RFID	14	2.79	1.805	11	2.91	1.300
Non-availability of ICASA spectrum	14	2.79	1.672	11	3.18	1.328
Privacy Issues	14	2.21	1.477	11	3.55	1.293
Security Issues	14	2.43	1.342	11	3.55	1.214
Legislative Issues	14	2.57	1.785	11	3.45	1.214
Frequency Issues	14	2.57	1.785	11	3.45	1.214
Other innovative solutions like 2-D barcode	13	2.15	1.281	11	2.82	0.982
Barcode is good enough for our applications	14	3.00	0.961	11	2.91	0.831
Our current app is good enough	14	3.14	1.099	10	3.10	0.876
Time consumed to change the system	14	2.43	1.342	10	3.00	0.943
Extra training for employee	14	2.57	1.222	10	3.00	1.054

The following Table A.4 summaries the descriptive statistics for the Question 18 "Which of the following is a constraint to your organisation?"

Table A.4 Which of the following is a constraint to your organisation?

Question 13	**Adopters**			**Non-adopters**		
Which of the following is a constraint to your organisation?	**N**	**Mean (µ)**	**Std Dev (σ)**	**N**	**Mean (µ)**	**Std Dev (σ)**
Adoption of new technology, like RFID by my organisation is a huge	15	2.80	1.699	11	3.36	1.517

policy decision given the business risk						
RFID represents a significant paradigm shift to our organisation	15	2.47	1.552	11	3.18	1.517
Lack of frequency allocation by ICASA has/will definitely impede deployment in my organisation	15	3.00	1.852	11	2.55	1.817

The following Table A.5 summaries the *combined* descriptive statistics for Question 14 on RFID and Barcode. The groups are combined due of the lack of differences between the means of the adopter and non-adopter categories. The combined values now reflect a view of RFID and barcode and therefore an interesting comparison may be undertaken of this.

Table A.5 Central Statistics for all respondents on RFID and Barcodes

Question 14 RFID and Barcode	**N**	**Mean (μ)**	**Std Dev (σ)**
RFID is a disruptive technology	26	2.35	1.424
RFID is better than barcode	22	4.09	1.291
RFID will be as omnipresent (ubiquitous) as barcode	26	2.12	1.141
It will/has taken take as long for my company to adopt RFID as it did to adopt barcode in the 80's	25	1.28	1.561
I am aware of the costs associated with barcodes	26	2.00	1.069
In time, RFID will replace barcodes completely	26	1.54	1.406

The following Table A.6 summaries the descriptive statistics for part of Question 13 "Security issues will be a challenge to RFID deployment in my organisation?"

Table A. 6 Security issues will be a challenge to RFID deployment in my organisation?

Question 13	Adopters			Non-adopters		
	N	Mean (μ)	Std Dev (σ)	N	Mean (μ)	Std Dev (σ)
Security issues will be a challenge to RFID deployment in my organisation	15	2.33	1.447	11	2.73	1.643
Privacy issues is a challenge to RFID deployment in my organisation	15	2.20	1.474	11	2.82	1.517

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