RHODES UNIVERSITY

Radio Frequency Identification (RFID) Adoption in the South African Retail Sector: An Investigation of Perceptions held by Members of the Retail Sector regarding the Adoption Constraints

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HAIDI LIU

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Abstract

Radio Frequency Identification (RFID) technology is a method of identifying unique items using radio waves that communicate between RFID tags and readers without line-of-sight readability. RFID technology provides great potential in many industries and a wide spectrum of possible uses. Areas of application include person identification, logistics, pharmaceutical, access control, security guard monitoring and asset management. One of the areas where RFID is being used and where it promises excellent results is the retail industry. While RFID systems have the potential to revolutionise the way products and goods are tracked and traced in the retail supply chain, barriers to its widespread adoption exist: for example; technical constraints, return on investment constraints, a lack of awareness and education and as well as privacy and security issues.

The research aims to identify the barriers to the adoption of RFID and to investigate the perceptions of RFID held by members of the retail sector in South Africa (SA). Current research and available literature are used to identify RFID adoption barriers and a conceptual framework on this subject is proposed, which is then verified by SA retailers' perceptions, established by means of a survey. Initial barriers to widespread adoption include a shortage in skills, a lack of standards, high costs associated with RFID devices, the difficulty of integrating with current legacy systems, and a lack of familiarity with the system. Finally, an enhanced framework is proposed, describing RFID adoption barriers within the South African retail sector. In summary, the framework is an outline of the barriers impacting RFID adoption in the SA retail sector that need to be considered and addressed. The framework identifies six categories of RFID adoption barriers, with each category containing two or more barriers relating to that particular category. These categories are Technological, Cost and return on investment, Privacy and security, Implementation, Organisational factors and People.

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Declaration

I acknowledge that all references are accurately recorded and that, unless otherwise stated, all work herein is my own.

H.D. Liu

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Chapter 1

Research Introduction

This chapter introduces the research problem. This is achieved by describing the research area and showing how it relates to the research problem on a general level. This chapter also presents a summary of the results and explains the organisation of this thesis.

1.1 Introduction

In the future, millions of people might interact directly with a Radio Frequency Identification (RFID) device. Recently, RFID has opened up doors to many new applications like remote identification, cheap real-time tracking of objects and high speed communication over short distances. This gives us the possibility of acquiring detailed information on real world systems. For example, we can trace products and items in real time in order to optimise processes in the retail sector.

1.2 Research Context

According to Zebra Technologies (2005), automatic identification, or Auto-ID for short, is the broad term given to a number of technologies that are used to help machines identify items. The aim of most Auto-ID systems is to increase efficiency, reduce data entry errors, and free staff to perform more value-added functions. A number of technologies belong to the Auto-ID family including barcodes, smart cards, voice recognition, optical character recognition and radio frequency identification (RFID).

Sandip (2005:2) defines RFID as a generic term for technologies that use radio waves to automatically identify individual items. RFID is a technology that is gaining acceptance as it moves from being expensive and experimental to increasingly affordable and practically implementable. According to Woods, Piszczalski, Davison, Steenstrup, Vining, Rozwell, Maoz, LeHong, Burt, Reynolds, Jones, Mahler, Hieb, Landry, Harris, White and Miklovic (2005), RFID technology is being applied in retail, supply chains, logistics, and other areas. As a result, general costs have dropped dramatically, making RFID more affordable.

Although there are implementation variations, RFID makes use of a microchip with an in-built radio transmitter. The radio transmitter and the microchip together are called the RFID tag (Sweeney, 2005:20). The RFID tag may be one of two types: active and passive. Active RFID tags have in-built power sources: the advantage of these tags is the reader can be much farther away and still receive a signal. Even though some of these devices are designed to function for up to 10 years, they do have limited life spans. Passive RFID tags, however, do not have in-built power sources,

can be much smaller and have a virtually unlimited life span. In both active and passive RFID tags, information can be stored within the microchip and the microchip attached to or implanted in an object (Sweeney, 2005:20).

There are several methods of identifying items using RFID. The most common of these is to store a serial number that identifies a product, and perhaps other information, on a microchip that is attached to an antenna. The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves returned from the RFID tag into a data form that can then be passed on to computers for processing (Bhuptani and Moradpour, 2005:24). As an example, a shopper in a grocery store could push a trolley containing goods through a checkout point. Instead of a cashier scanning individual items, an RFID scanner would automatically scan the contents of the trolley and even complete the purchase transaction (Eckfeldt, 2005).

RFID has wide application and besides being used for stock inventory, can be used for wildlife monitoring and even triggering processors down an oil well (Ward, 2006). The most common applications are tracking goods in the supply chain, tracking assets, tracking parts movement in a manufacturing facility, security and payment systems that let customers pay for items without using cash (Sweeney, 2005:57). At present, businesses are focused on using RFID to streamline data collection and data consistency; for example, tracking products through the manufacturing cycle and then locating them at warehouses and retailers. With RFID, each product can be identified by physical location, manufacturing history and distribution path (Borriello, 2005).

As RFID technology improves, so does the application of RFID broaden in scope. However, problems associated with the implementation of RFID persist. These include cost variation, the lack of business case study, reader and tag collision, RFID privacy and security issues, radio frequency interference and lack of standards.

Given the aforementioned RFID implementation issues, it is not surprising to find that members of the retail sector have varied perceptions regarding the usability of the technology. It is crucial to understand perceptions of RFID held by members of the

South African (SA) retail sector so that a model can be constructed that outlines these concerns.

1.3 Goals and Objectives of the Research

The overall goal of the study is to investigate the barriers to RFID adoption in the retail sector of South Africa. In doing so, the research will:

- Investigate RFID technology in an attempt to gain adequate knowledge and understanding about the technology.
- Investigate and identify some of the factors that influence the acceptance of an innovation such as RFID.
- Analyse the perception of RFID systems held by South African retail managers in an attempt to determine the aspects of RFID that are considered problematic for RFID adoption in a retail sector.
- Synthesise a framework outlining the concerns expressed by retail management on the adoption of RFID within the retail sector.

1.4 Research Methodology

The research paradigm for this study is based on the positivist framework. A quantitative approach will be conducted via the use of a survey instrument that will be assembled and delivered to members of the retail sector within South Africa. Data collected through the survey will be statistically analysed in order to identify and describe those variables that play a major role in the perceptions of RFID held by members of the retail sector.

Research steps:

- A literature survey will be conducted and RFID technology within the retail sector will be explored specifically in an attempt to isolate those issues believed to be pertinent to addressing RFID in the retail sector.
- A framework describing the concerns raised in the literature survey will be constructed.
- A questionnaire informed by issues raised in the framework will be employed in which quantitative data will be collected. Where possible, structured

questionnaires will be conducted by means of a Web-based survey system, failing which surveys will be conducted telephonically.

- The population of the study will be confined to members of the retail sector within the context of South Africa. The respondents involved will be approximately 30 retail organisations.
- Standard analysis will be performed on data collected using appropriate software applications. (Statistica ® and R®)
- The survey results will be used to identify common adoption concerns considered as an impediment to the uptake of RFID in the South Africa retail sector.

The final result of the research study is a framework of what SA retailers consider to be barriers of RFID adoption.

1.5 Summary of Results

This research makes contributions in the following areas:

- Retail Supply Chain Management

  Retailers are focusing on supply chain efficiency in order to stay competitive and in order to improve their business efficiency, and it is important for them to reinvest in new technologies.

- RFID technology

  RFID technology can be used to improve efficiency and effectiveness in the retail sector. In addition, there are major advantages compared to the current barcode systems. RFID systems consist of three major components: tag, reader and RFID software. There are also two major standards currently being adopted: they are EPCglobal and International Organization for Standardization (ISO). RFID has a variety of possible applications, including access control and security, transport and logistics, and supply chain and medical applications.

- Diffusion of innovation

  Diffusion of innovation is an approach that focuses on the factors influencing the approval of an innovation that result in general acceptance by the public and potential adopters. Principles and theories that were studied revealed some of the key constructs that influence the acceptance of an innovation. The theories and principles explored are:

  - Diffusion of innovation
  - Adoption of information technology innovation theory
  - Theory of reasoned action
  - Social cognitive theory
  - Technology acceptance model
  - Theory of planned behaviour
  - Model of personal computer utilization

- RFID adoption barriers

  RFID technology revealed many barriers which currently hold back potential adopters, hence the low adoption rate, especially in the South African retail sector. Some of the barriers identified are: cost challenges, standards challenges, return on investment (ROI) challenges, privacy and security challenges, lack of awareness and education, technical constraints, business process change constraints and implementation challenges.

- Enhanced framework of the barriers of RFID adoption

  The majority of the barriers identified were confirmed by South African retailers, and should be considered and addressed when adopting RFID technology. An enhanced framework of the barriers that influence the adoption of RFID in the South African retail sector was provided. These include lack of standardisation, poor accuracy and read rates, high costs associated with RFID technology, privacy and security concerns, implementation challenges, lack of awareness, unskilled labour, lack of support and unwillingness to use the technology.

1.6 Thesis Organisation

The thesis is organised into the following chapters:

Chapter 1: Research Introduction

Chapter 1 introduces the research area. This is achieved by describing the research area and showing how the research area relates to the research problem on a general level. This chapter also presents a summary of the results and explains the organisation of this thesis.

Chapter 2: Supply Chain Management and AIDC Technology

Chapter 2 provides a detailed description of the supply chain and its management process, followed by a brief explanation of supply chain management in the retail sector.

Chapter 3: RFID Technology and its Application

Chapter 3 provides the theoretical grounding for the rest of the thesis. The chapter introduces automatic identification technology, particularly RFID. A definition of RFID is provided, followed by the evolution of RFID technology. A comparison of barcoding technology with that of RFID is presented prior to explaining the components of RFID technology. Further, standards and regulations relating to this technology are explored. Finally, the application of RFID technology in different areas is discussed.

Chapter 4: Diffusion of Innovation

Chapter 4 explores the issues that influence the diffusion of innovation as they relate to the adoption of a new innovation, such as RFID. It seeks to identify factors facilitating and inhibiting such adoption. Further, supplementary theories and models are investigated in addition to diffusion of innovation theories for an in-depth understanding of the diffusion of innovation.

Chapter 5: Adoption Barriers to RFID technology in the Retail Sector

Chapter 5 identifies the challenges that retail supply chains encounter when adopting RFID technology. These barriers are then discussed and analysed to establish the

factors that influence RFID adoption in the retail sector, which are then used for the proposed framework.

Chapter 6: Proposed Conceptual Framework of the Barriers of RFID adoption in the South African Retail Sector

Chapter 6 uses the investigation into diffusion of innovation in Chapter 4 and barriers to RFID adoption in Chapter 5 as the basis for a framework describing the barriers to RFID technology in South African retail sector. The chapter presents a conceptual framework in detail. This chapter also details the hypotheses that form the basis of this empirical study is intended to explore.

Chapter 7: Research Methodology

Chapter 7 explores the research methodology used to validate the framework proposed in Chapter 6, by investigating RFID adoption barriers as perceived by SA retailers. The research design is explained, the hypotheses are defined, and the data collection method is also provided.

Chapter 8: Results

Chapter 8 analyses the data gathered from the questionnaire and interprets the results using statistical methods. A detailed analysis of the hypothesis testing process is provided.

Chapter 9: Enhanced Framework of the Barriers of RFID adoption in the South African Retail Sector

Chapter 9 provides a general discussion of the overall result. Further discussion concerning other results is also explained. Recommendations about the changes in conceptual framework are made, and finally an enhanced framework of the barriers of RFID adoption in the South African (SA) retail sector is proposed.

Chapter 10: Conclusion and Future Research

Chapter 10 provides the conclusion to this research. The contributions of the research to the body of knowledge are provided. Future areas of research are recommended, followed by concluding remarks.

Chapter 2

Supply Chain Management

This chapter provides a detailed description of the supply chain and its management process, followed by a brief explanation of supply chain management in the retail sector.

2.1 Introduction

One of the most important aspects of supply chain management systems is managing all aspects of inventory throughout the supply chain. While several supply chain management systems exist, mostly supported by technology, a gap still exists between the digital and physical worlds. A database entry indicating that an item is stored at a particular location is nothing more than a snapshot taken at the moment of last human intervention. As soon as the item is moved, the database is no longer accurate. This necessitates someone physically verifying that the object is no longer available.

New technology enables the automatic identification or auto-ID of physical objects. Auto-ID is a core component of automated inventory control systems and retail supply chain management. Inventories that were previously managed via manual processes can now have an RFID tag attached to them, resulting in real-time updates along the entire supply chain. The 'snapshots' referred to earlier can be converted to continuously updated real-time information. Today many large international retailers and suppliers such as Wal-Mart, Target, Albertson, Metro groups, Tesco, Gillette Co., Johnson & Johnson and Automotive industries, to name a few, are introducing RFID into their supply chains.

2.2 The Supply Chain

Many organisations today are forced to increase their global market share in order to survive and sustain growth objectives, while at the same time defending their domestic market share from international competitors. The challenge is how to expand the global logistic and distribution network in order to ship products to customers who demand them in a dynamic and rapidly changing set of channels. Strategic positioning of inventories is essential, so that products are available when the customer wants them (Handfield and Nichols, 2002:38; Shepard, 2004:2).

According to Chopra and Meindl (2004), a supply chain consists of all parties directly or indirectly involved in fulfilling a customer request. Mentzer, deWitt, Keebler, Min, Nix, Smith and Zacharia (2001:5) suggest that a supply chain is a set of three or more entities, organisations or individuals, directly involved in upstream and downstream flows of products, services, finances, and information from a source to a customer.

Stern, El-Ansary, Coughlan and Anderson (2001:513) agree with Mentzer *et al.* (2001:5), and suggest that a supply chain's beginning point is where raw materials are extracted and the end point is where goods and services are consumed.

The supply chain is a complex, multi-stage process which involves everything from the procurement of raw materials to developed products, and their delivery to customers via warehouses and distribution centers. Supply chains exist in service, manufacturing and retail organisations. A typical supply chain includes suppliers, manufacturers, distributors, retailers and customers. Within each phase, such as retail, the supply chain includes all functions involved in receiving and fulfilling customer requests (Chopra *et al.*, 2004). These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service. Supply chains are essentially a series of linked suppliers and customers involved in getting a product to the ultimate customer (Handfield and Nichols, 2002:9).

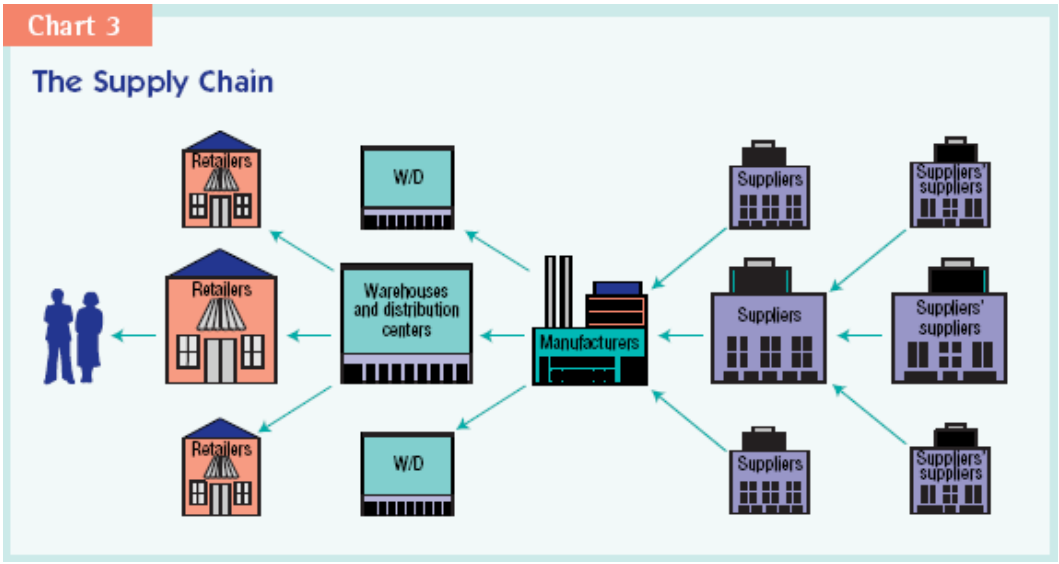

Figure 1: Supply Chain Network (Thomas, 2005)

Domenica, Poojari, Koutsoukis and Mitra (2003:8) suggest that long-term competitiveness depends on how well the company meets customer preferences in terms of service, cost, quality, and flexibility. Well designed distribution channels will lead to greater efficiencies and minimised resource usage, ultimately providing companies with a competitive edge. Maintaining quality of service while optimising

inventory levels and minimising backorders remains a constant challenge for supply chain companies (Domenica *et al.*, 2003:8). To achieve this, many strategic decisions must be taken and activities coordinated. This requires careful supply chain design and management. The design of a supply chain represents a means by which a company can innovate, differentiate, and create value. The challenge of supply chain design and management lies in having the ability to design and assemble assets, organisations, skills, and competences. It encompasses the team, partners, products, and processes.

Supply chain efficiency has a direct impact on the profitability of an organisation, and therefore many large organisations have strategically invested heavily in systems and IT infrastructure designed to control inventory, track products and manage associated finance (Domenica *et al.*, 2003:9).

2.3 Management

In order for an organisation to leverage the benefits discussed in the previous section, it needs to provide sound supply chain management. Most authors define management as the coordination of divided activities (who does what) or managerial process or functions in an organisation (Rozman, 2000:7). Donnelly, Gibson and Ivanchevich (1995:4) define management as the process undertaken by one or more individuals to coordinate the activities of others to achieve results not achievable by one individual acting alone. Hellriegel and Slocum (1996:302) define coordination as the integration of activities performed by separate individuals, teams and departments. In a very simplified way, management can be described as the art of getting things done through organising other people in accordance with business plans.

Supply organisations are often large with management typically spread among many functions. Integrated supply chain management is crucial to ensure efficient coordination of decisions across the supply chain (Chopra, 2001:3).

2.4 Supply Chain Management (SCM)

Although the concept of supply chain management has been investigated over a decade, there is still no consistent definition. As a result, there is generally a lack of consistency in meaning and clarity across the diverse definitions of supply chain

management available in the literature. Hugo, Badenhorst-Weiss and Van Rooyen (2002:29) define supply chain management as a management philosophy aimed at integrating a network of sources of supply, internal linkages inside the organisation and distribution. Hugo *et al.* (2002:29) suggest that supply chain management must encourage specific processes and activities that will ultimately create and optimise value for the customer in the form of products and services which are specifically aimed at satisfying their demands. Moreover, Handfield *et al.* (2002:8) and Viswanadham (2002) suggest that supply chain systems promote efficiency and effectiveness by automating processes, beginning with raw material procurement and ending with timely delivery to satisfied end users. Thus, supply chain management is getting the right things to the right places at the right time by using the right systems efficiently and effectively for maximum profit (Thomas, 2005)

Both Bolumole (2000:2) and Hugo *et al.* (2002:29) suggest that supply chain management offers an integrated philosophy for managing organisations' purchasing and distribution processes based on a marketing perspective. Persson (1997:58) argues that supply chain management is a homogenous management concept, wherein the overall objective is to contribute to improvements in the company's bottom line or profitability. Related objectives include reducing costs by optimising inventory levels and increasing revenues by improved customer service. This according to Persson (1997:58), could be achieved by improving coordination and integration along the material flow, as well as fostering effective and efficient (win-win) relationships resulting in an end customer focus.

Chopra (2001:3) suggests that supply chain management involves the management of flows between and within stages in a supply chain to maximise total profitability. These functions include marketing, operations, distribution, finance, and customer service.

Furthermore, supply chain management is the integration and management of supply chain organisations and activities through cooperative organisational relationships, effective business processes, and a high level of information sharing to create high performing value systems. There are several supply chain management systems available. Some of the more common systems are discussed below:

- Enterprise Resource Planning (ERP) which is an information system or process integrating all manufacturing and related applications for an entire enterprise. ERP systems permit organisations to manage resources across the enterprise and completely integrate manufacturing systems (Kremzar and Wallace, 2001:5).
- Warehouse Management Systems (WMS) are usually implemented using software that integrates mechanical and human activities with an information system to effectively manage warehouse business process and direct warehouse activities. These systems automate receiving, putting away, picking, and shipping in warehouses.
- Supply Chain Management (SCM) systems are used to reduce inventory, therefore allowing organisations to constantly monitor and optimise stock levels, making sure that the right quantities are ordered timeously (Simchi-Levi D., Kaminsky and Simchi-Levi, E., 2000:4). There are two main types of SCM software:
    - Planning applications that use advanced algorithms to determine the best way to fill an order.
    - Execution applications which track the physical status of goods, the management of materials, and financial information involving all parties.
- Customer Relationship Management (CRM) software solutions that help enterprise businesses manage customer relationships in an organised way. An example of a CRM system would be a database containing detailed customer information that management and salespeople can reference in order to match customer needs with products and inform customers of service requirements (Zaltman, 2003; Zuboff and Maxmin, 2002).

2.5 Retail Supply Chain

The retail industry is an important part of the supply chain, and plays a major role in the whole supply chain process. According to Kent and Omar (2003:5), the retail industry is the composition of retail outlets that sell merchandise to consumers. Retailers purchase items from a supplier or wholesaler for resale at a profit. Retailers may offer only one type of product, where there is little competition and a substantial

markup, such as a motor dealer. Alternatively, retailers may offer many different products or models, so that customers have a choice of finding an item in store, such as a supermarket or convenience store. Some retailers earn a small profit on many items and rely on the volume of sales to account for their profits. For these reasons, retailers must constantly assess whether items for sale are "turning over" properly, and if necessary, retire certain products and introduce new products for sale (Kent *et al.*, 2003). In addition, customers are a major influence in the success of retail supply chains; thus, customer satisfaction is an important factor in determining overall profitability.

Both Hugo *et al.* (2002:346) and Kent *et al.* (2003:14) maintain that it is critical to examine all the linkages in the supply chain, as well as the technology and methodology used during the process, to ensure that retailers have the right products, in the right place and at the right time. Failure to achieve all these requirements will reduce profitability and consume cash unnecessarily.

In retail stores, the inability to rapidly locate items is a common problem. Retailers could appear to be out of stock of a product, when in fact the product might be available in the back of the store or might have been placed on the wrong shelf. Automatic identification technology has been proposed as a means to improve the ability to track inventory and to locate objects.

2.6 Conclusion

The retail supply chain presents many challenges that have spawned numerous attempts to increase efficiency and effectiveness. The use of RFID has an enormous impact on minimising the effect of these challenges while increasing sales and reducing supply chain costs. RFID is a technology for identifying objects wirelessly by attaching tags which can then be interrogated via readers. Many retail supply chains like Wal-Mart, Tesco and CVS are currently planning to replace traditional barcodes with these high-tech tags. The technology itself has been available since the Second World War, but only recent developments are resulting in the tags becoming cheaper and smaller and therefore more viable as a replacement option for the more traditional barcode, especially in the retail sector.

Chapter 3

RFID Technology and its Application

The previous chapter introduced the supply chain and issues surrounding supply chain management. This chapter investigates Automatic Identification Technology (AIDC) and in particular Radio Frequency Identification (RFID), which may be used as a tool to automate and optimise supply chain management. A definition of RFID is provided, followed by a historical perspective of RFID technology. Further, RFID technology is demystified, compared and contrasted to barcode technology (the prevalent AIDC technology used currently). Finally, the application of RFID is discussed.

3.1 Introduction

The increasing need for efficient management of goods and assets in supply chains has led to the development of automatic identification systems, particularly the recent growth in RFID technology. RFID technology allows for the identification, data collection, and information storage on assets and goods. An ideal RFID system is one that enables low cost implementation of data transfer without any need for human intervention. Today RFID can be found as an alternative payment option for tollbooths and in convenience stores. It is used in places of employment for access control; and corporations use this technology as a tracking device on merchandise.

The goal of this chapter is to familiarise the reader with the fundamentals of RFID technology. It starts by highlighting the differences between barcoding and RFID technology. After a system overview has been given, the technical background of RFID components is presented followed by the properties of various RFID standards. Finally, examples of various applications of RFID technology are discussed.

3.2 Automatic Identification Technology

Automatic Identification and Data Capture (AIDC) refers to methods of identifying, collecting and processing data via computer systems with minimal human intervention (Karygiannis, Eydt, Barber, Bunn and Phillips, 2006:2-1; Finkenzeller, 2003:2). AIDC is believed to provide efficiencies in business processes through the ability to collect and process accurate source data (Finkenzeller, 2003:2; Smith, 2005: 26). AIDC technology, which includes barcodes, radio frequency identification, magnetic stripes, optical character recognition (OCR), smart cards and voice recognition, is used for marking individual items, multipacks, air pallets or containers, while in-storage, in-process or in-transit (Finkenzeller, 2003:2-6).

In particular, the use of RFID-tagged objects coupled with smart shelves that include RFID readers has been proposed as a means of efficiently tracking the presence of products in a retail environment. Excellent retail supply chain management revolves around understanding and balancing three key dimensions of availability, inventory and cost (Kent *et al.*, 2003:14). Managing these dimensions efficiently can result in supply chains that improve business performance and drive competitive advantage.

3.3 Radio Frequency Identification

Radio Frequency Identification (RFID) is best described as a wireless memory chip or a "smart tag" that is attached to both a product and its transport packaging (Sandip, 2005: 1; Roberts, 2006). RFID technology is a generic term for one of the fastest growing automatic data collection technologies that utilise wireless radio communication to uniquely identify objects, animals, or people by using radio frequency signals (Bhuptani and Moradpour, 2005: 24). At present, RFID technology suppliers are competing to provide a complete solution that supports decision-making, process optimisation, improved customer satisfaction, and thus, increased organisational profit. Furthermore, the benefits of RFID include a vast reduction of human errors, faster data collection, hands-off operation, and application in harsh environments.

3.3.1 RFID in the retail sector

An increasing number of retail companies worldwide are embracing RFID technology as a means of rapidly identifying multiple items in a single container and in a speedy manner. This is currently not possible using widely accepted barcoding systems (The Retail Bulletin, 2004). Retailers adopting RFID technology are looking for ways to increase visibility and traceability, reduce out-of-stock scenarios and reduce labour costs (Metro Group, 2004: 10). The technology's high level of accuracy and security makes it ideal for data collection in the retail sector.

Some of the world's largest retailers such as Wal-Mart and Metro in America have committed to using RFID technology within their supply chain management (Bhuptani *et al.*, 2005: 31; Shepard, 2004:144). Wal-Mart in particular mandated that their top 100 suppliers use RFID tags on all product deliveries by 2005 (Wal-Mart, 2005). Although time scales were shifted until the end of 2005 for its completion, the process was successfully accomplished and further expansion is currently ongoing (Wal-Mart, 2006). At present, local retailers such as Pick 'n Pay and Shoprite are aware of RFID and in some cases are investigating the technology.

3.3.2 History of RFID

3.3.2.1 RFID and World War II

While the implementation of RFID in the retail sector is a recent innovation, RFID technology per se is not a new concept and according to Bhuptani *et al.*, (2005: 25), can be traced back to World War II, when the British military needed to find a way to identify whether an approaching aircraft was friend or foe. The number one cause of fatalities among the allied air forces in World War II was friendly fire. For this reason, transponders that could be set to a pre-determined frequency were developed and installed in Allied aircraft. This enabled the military to identify approaching aircraft prior to visual confirmation (Landt, 2001: 4). Even today, as more sophisticated navigation technology becomes available, the military still uses various forms of RFID.

3.3.2.2 Inventory Tracking

During the 1980s, RFID was used by various concerns for the tracking of goods and livestock. The Compaq Computer Company began using RFID tags to trace components through the production process (Bhuptani *et al.*, 2005: 26). The railway industry has used RFID to track nearly every rail car in North America. The agricultural industry has also used RFID tags to trace livestock during this period (Landt, 2001: 5).

3.3.2.3 Consumer applications

More recently, RFID has been used in various consumer applications, perhaps the largest being electronic article surveillance (EAS), which is article security for retail merchandise (Landt, 2001: 4). Additional applications include car keys with built-in RFID transponders which deactivate the engine immobiliser when someone attempts to start a car. BP service stations in South Africa can provide customers with an RFID embedded tag which is linked to the customer's bank account. The system which is known as the BP FuelMaster system allows consumers to refuel their vehicles and then expedite payment by using the RFID embedded tag as an identification mechanism in place of a petrol card (RFID International, 2004).

Table 1 provides a timeline of the major RFID milestones that have been reached over the past 60 years.

Decade	Event
1940s	- Radar refined and used. Major World War II development effort. - RFID invented in 1948.
1950s	- Early explorations of RFID technology, laboratory experiments.
1960s	- Development of theory of RFID. - Start of application field trials.
1970s	- Explosion of RFID developmental work for electronics article surveillance (EAS) to counter theft, improve animal tracking, vehicle tracking and factory automation. - Tests of RFID accelerate. - Very early adopter implementations of RFID.
1980s	- Commercial applications for RFID enter mainstream.
1990s	- Emergence of standards. - RFID systems, such as electronic toll collection, deployed throughout the United States. - RFID becomes part of everyday life with a single tag capable of handling multiple applications such as electronic toll collection, car park access and fare collection, gated community access and campus access.
2000 to 2003	- Development and implementation of RFID for supply chain management, healthcare/pharmaceuticals and library information systems.
2003 to present	- Major retailers mandate that suppliers implement pallet and case-level tagging by January 2005, sparking rapid RFID research and development.

Table 1: RFID Timeline (Landt, 2001:7; Bhuptani *et al.*, 2005:24-32; Shepard, 2004:42; Roberts, 2006)

3.3.3 Barcode versus RFID

The most obvious technology that is comparable to RFID for many application areas is barcoding. Both barcoding and RFID technologies involve the addition of a "tag" or "label" to an item that contains information about that item which allows it to be identified by a computer system.

Currently, barcode technology is very popular in many areas, such as supply chains, distribution, manufacturing and retail, because it is used as the industry standard for item identification. There are two types of barcodes. The first and most common type is the one-dimensional (1D) or linear barcode, which is based on a series of bars and spaces to represent data. A 1D barcode is read using a laser to scan across the width of the bars (Sandip, 2005: 115). The second type is the two-dimensional (2D) barcode, which uses small geometric shapes to represent data. The 2D barcode system stacks shapes or uses a matrix configuration to allow more information to be stored in the same space as the 1D barcode system (Sandip, 2005: 116). A 1D barcode requires only a laser scanner to read a single narrow band across the width of the barcode. Alternately, a 2D barcode requires the laser scanner to read the code both horizontally and vertically.

According to Yeung, Mason, Chimka and Greiner (2003), barcoding technology has the following limitations:

- Barcodes are used to identify types of products, not unique individual items. Therefore, a reader will not be able identify individual product in a pack, its expiration data, and other pertinent data.
- Barcodes need to be scanned at a set orientation. In other words, barcodes require line of sight, so they usually have to be oriented toward a scanner in order to be read.
- Barcodes are not reliable in harsh environments, and do not work if the bars or geometric figures become damaged.
- Barcodes cannot be updated or rewritten, unless the code is reprinted on a different label.

The idea of using RFID in applications such as supply chain management is a new concept. RFID can be used as a substitute for barcode systems, as it uses radio frequency to identify items and does not require line of sight. For this reason, RFID has been nicknamed the "wireless" or "radio" barcode (Sandip, 2005: 116). As shown in Figure 2, barcoding technology has reached a maturity level whereby there are diminishing returns in terms of supply chain efficiency, whereas RFID is considered to provide a significant "step up" in terms of supply chain efficiency.

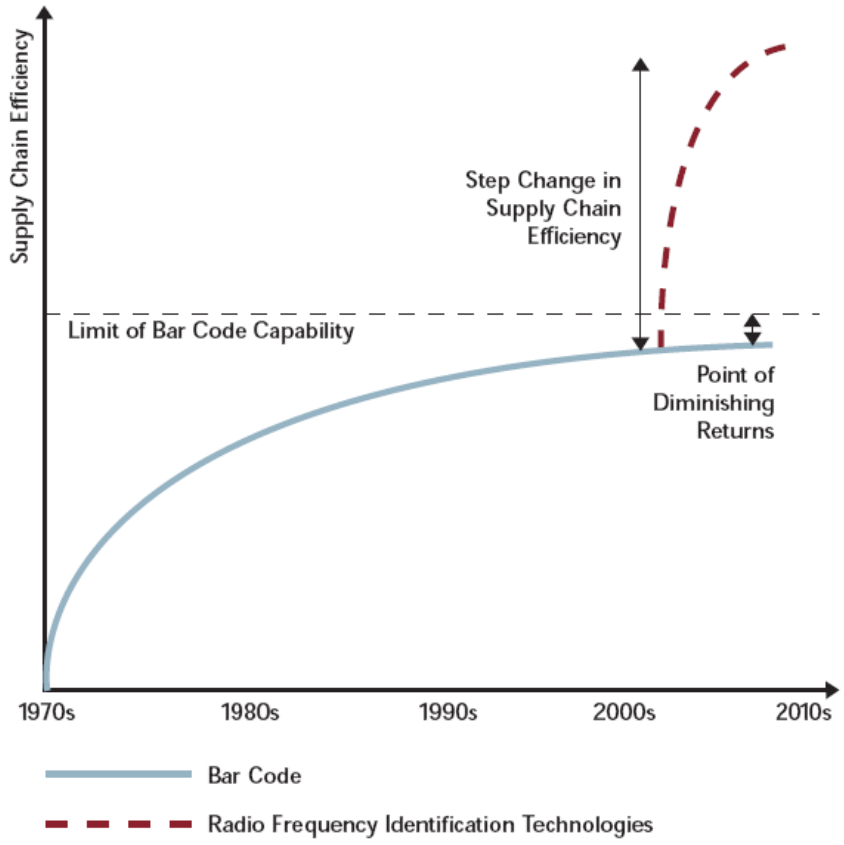

Figure 2: Comparison of the efficiency between the use of barcode and RFID in the Supply Chain (Mitchell and Chappell, 2003)

The merits of substituting barcode technology with RFID technology have been debated over the last few years. The low cost of barcode labels relative to the cost of RFID tags, given that barcodes are effective in certain environments, should result in barcode technology coexisting with RFID technology for many years (Sandip, 2005: 132).

3.4 The advantages and disadvantages of using RFID Technology

As with many advanced technologies, there are both advantages and disadvantages to using RFID. However, the majority of these disadvantages can be overcome in order to maximise the utility of the technology.

3.4.1 Advantages

Although RFID technology should not be considered a panacea for flawed business practices, if integrated correctly, it can help to dramatically reduce business overheads. This is achieved by accelerating order processing and increasing responsiveness to customer demand by enabling the flow of real-time information about goods within the supply chain in an efficient manner (Sandip, 2005: 52). RFID improves the rate and quality of data being collected and can help assist in reducing time and labour costs (Lee and Ozer, 2005). If optimally implemented, the benefits of the reduced costs can be passed down the supply chain to the consumer. In addition, RFID systems can prevent and detect theft by triggering an alarm when an item has not been passed through a checkout reader (Sandip, 2005: 52).

Effectively utilising the data and capabilities that an RFID system provides can help to improve inventory visibility, which in turn can lead to lower stock levels (Luckett, 2004). Therefore the overall inventory carrying cost is reduced, and working capital is freed up (Sandip, 2005: 60).

RFID improves product traceability immensely. An RFID system can provide data and trigger points, and the host system uses this information in order to support supply chain management and task management such as life cycle control, automation of transactions and settlements, logistic efficiency and rationalisation of manufacturing control. This turns into improved productivity (Sandip, 2005: 52). Radio frequency readers can read data at a distance, without any need for line-of-sight scanning or physical contact. This is possible because readers can automatically recognise and differentiate all the tags in their reading field. This provides additional flexibility for material handling, packaging and sorting operations. Individual items can be identified, whereas the current barcode system does not distinguish between

two items of the same type (e.g. two identical packs of popcorn). As a result, the shopper will experience shorter queues and quicker checkout times, while merchants can keep track of inventory in real-time, so that products that are running low can be re-shelved and unnecessary inventory reduced (Sandip, 2005: 52).

Companies that use RFID to uniquely identify items and take advantage of the information collected can expect to see major benefits. Barcode labels, which must be physically placed on packaging because of line-of-sight requirements, are inclined to fade in harsh environments, which results in delays of recording information. RFID technology enables much greater accuracy in tracking and tracing goods and the containers that hold them, even in harsh environments, since RFID tags do not wear out and do not require line-of-sight to function (Sandip, 2005: 52). Additionally, RFID can uniquely identify products, cases, and other items, which increases productivity and saves on labour costs in comparison to barcode (Sandip, 2005: 115; Lee *et al.*, 2005). RFID virtually eliminates the need to have people locate items and manually scan barcodes.

3.4.2 Disadvantages

Unfortunately, as with most technology, RFID has its limitations. As mentioned, RFID tags and transponders transfer information via radio waves. These radio waves can be subject to interference, mainly from metal and liquid products, especially when merchandise is packaged in metal cans or containers (Sandip, 2005: 60). These potential sources of interference must be recognised and accounted for during system planning. Tags with lower frequencies tend to read better near metal or fluids. This is because higher frequency radio waves tend to bounce off metal and are easily absorbed by liquids (Sandip, 2005: 60; Luckett, 2004).

Unlike barcodes, it is quite possible for a bad or damaged chip at the item level within a batch of goods to go undetected when passing through the reader (Sandip, 2005: 60). This is, unless there is a database system that already has a record of how many items are expected to be scanned by the reader, allowing the system to cross-check against the figures recorded in the database. A damaged barcode, on the other hand, can be immediately detected when a “no read” scan is recorded.

Consumers could see cost increases passed on to them during the initial stages of RFID implementation. This is due to the costs incurred by the supplier for necessary changes to the information systems infrastructure (Sandip, 2005: 60). Additionally, because RFID tags are in the early stages of implementation, it is expected that there will be more instances of defective RFID tags. If an item has a defective RFID tag that cannot be read, the item would either need to be scanned by way of a barcode, or go through manual entry during checkout, inventory and receiving, which reduces efficiency (Sandip, 2005: 60).

3.5 Components of an RFID System

Having discussed some of the advantages and disadvantages to using barcode and RFID technology, the following section explores the components of an RFID system in greater detail.

According to Finkenzeller (2003, 7), Sandip (2005, 7) and Shepard (2004, 55), a basic RFID system consists of three components:

- A programmable RFID tag or transponder for storing data (exception: read-only tags).
- An antenna to facilitate the reading and writing of data on the tag. In the case of a passive tag, the antenna assists in powering the tag.
- A reader that encodes or decodes the data in the tag's integrated circuitry. In the case of passive RFID systems, the reader also supplies power to the tag.
- Software components that are required to communicate between the application and the hardware, such as tags and readers. These components include RFID system software, middleware and host applications.

3.5.1 The RFID Tag

The RFID tag is also known as a transponder. The programmable RFID tag is an integrated circuit (IC) embedded in a thin film medium. Information stored in the tag is transmitted via radio frequencies to the RF reader (Bhuptani *et al.*, 2005: 40; Finkenzeller, 2003: 7; Shepard, 2004:57). The performance of the RFID tag is determined by factors such as the type of IC used, the read/write capability, the radio frequency, the read range, and external factors such as the environment and packaging

(Bhuptani *et al.*, 2005: 40). RFID tags come in a range of shapes and sizes. The following are the most common:

- Label: the tag is flat, thin and flexible.
- Ticket: it is a flat, thin and flexible tag on paper.
- Card: a flat and thin tag embedded in a tough plastic for durability.
- Glass bead: a small tag in a cylindrical glass bead, typically used for animal tagging.
- Integration: the tag is integrated into the object.
- Wristband: a tag inserted into a plastic wrist strap.
- Button: a small tag encapsulated in a rigid housing.

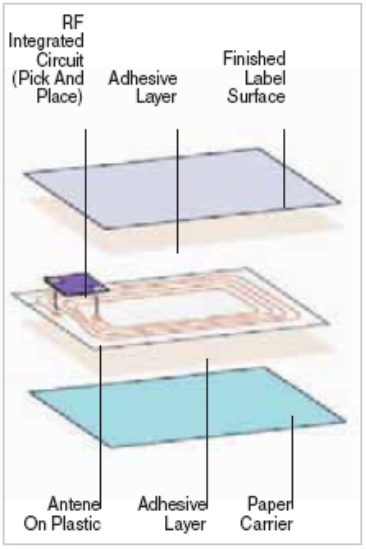

Figure 3: Structure of a Typical Passive RFID Tag (UPM Rafsec, 2006)

Figure 4: Sample of Passive RFID Tag (UPM Rafsec, 2006)

3.5.2 Active, Passive and Semi-Passive RFID tags

3.5.2.1 Active tags

Active tags are manufactured with their own in-built power source to power the tag operation. As a result of an in-built battery, active tags can operate over a longer range but have a shorter service life and are more costly (Bhuptani *et al.*, 2005: 40; Shepard, 2004:57). Active tags have an extended reading distance, which can be many metres. Since active tags work similarly to beacons, the range could be

extended even further with each additional active tag that is within range (Sandip, 2005: 14).

3.5.2.2 Passive tags

Passive tags do not have an independent power supply, and receive their power from the host reader. Some RFID tags can store a few kilobits of data (around 2 kilobits). These tags are designed for short-range simple tracking and monitoring applications (Sandip, 2005: 9; Shepard, 2004:57). Passive tags rely on the radio waves emitted by RFID readers for their power source, instead of relying on battery power. Power is derived from the active RF reader's electromagnetic field. This essentially gives passive tags an unlimited lifespan (Sandip, 2005: 9). Because passive tags do not have a battery, they are generally smaller and lighter in comparison to active tags. However, passive tags have a read range which is shorter and much smaller than that of an active tag. For a lower cost implementation, passive tags are a more attractive solution (Sandip, 2005: 9).

3.5.2.3 Semi-passive tags

Semi-passive tags are very similar to passive tags except for the addition of a small in-built power source, which allows the tag to be constantly powered, removing the need for the antenna to be designed to collect power from the incoming signal. Semi-passive RFID tags are therefore faster in response, though less reliable and not as powerful as active tags (Sandip, 2005: 16).

The following table compares the technical characteristics of Active and Passive RFID tags

	Active RFID tag	**Passive RFID tag**
Tag Power Source	Internal to tag	Energy transferred from the reader radio frequency
Tag Battery	Yes	No
Required Signal Strength from Reader to Tag	Continuous, very low	Only within field of reader, very high (must power the tag)

Available Signal Strength from Tag to Reader	High	Very low
Communication Range	Long range (100m or more)	Short or very short range (3m or less)
Multi-Tag Collection	Collects 1000s of tags over a 28328 m^2 region from a single region Collects 20 tags moving at more than 160 mph	Collects up to a few hundred tags within 3 meters from a single reader Collects 20 tags moving at 5 mph or slower
Sensor capability	Ability to continuously monitor and record sensor input and data/time stamp for sensor events	Ability to read and transfer sensor values only when tag is powered by reader, but no date/time stamp
Data storage	Large read/write data storage (128KB) with sophisticated data search and access capabilities available	Small read/write data storage (e.g. 128 bytes)

Table 2: Summary of Difference between Active and Passive RFID technology (Bhuptani *et al.*, 2005: 39-42; Sandip, 2005: 14-20)

3.5.2.4 Read-Only, Write Once/Read Many (WORM) and Read/Write Tags

Information that can be stored in an RFID tag is defined by the tag's read/write characteristics. For a read-only tag, stored information is recorded onto the tag during the manufacturing process and cannot be erased. Typically, the information stored is a unique serial number that allows one tag to be distinguished from another (Sandip, 2005: 18; Roberts, 2006). Read-only tags are therefore useful for identifying an object, much like the license plate of a car. WORM tags are preprogrammed but additional information can be added if space permits. With read-write tags, information can be added to the tag or rewritten over existing information, when the tag is within range of a reader or an interrogator (Sandip, 2005: 18; Roberts, 2006). Primary rewrite applications are pharmaceutical applications and shipping containers

full of miscellaneous products, where bottles or containers are reused many times, and information needs to be updated. Rewrite tags are more expensive than read-only tags, so these systems are typically used to track high value or critical items (Bhuptani *et al.*, 2005: 41; Sandip, 2005: 18; Roberts, 2006).

Depending on the application, a rewritable tag can be updated hundreds of times, and its reusability can help to reduce the number of tags that need to be purchased (Sandip, 2005: 18). Also important, is the ability to modify or add to the information stored, which is not possible with barcode technology. Rewritable tags can also be locked to operate as read-only tags. The number of writes is limited by similar limitations such as flash memory. After thousands of rewrites, reliability decreases (Sandip, 2005: 18).

3.5.3 RFID Antenna

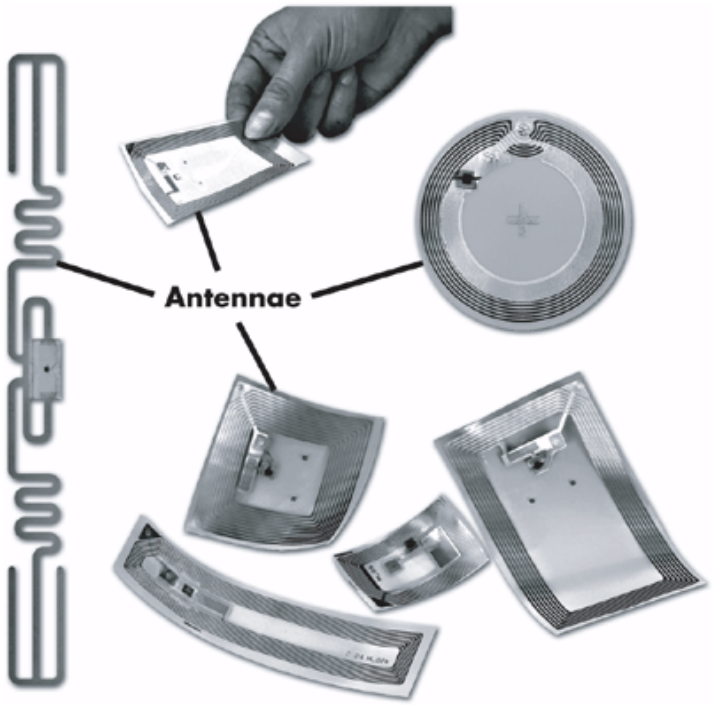

Figure 5: Typical Passive RFID Tags with Antennae Highlighted (Bhuptani *et al.*, 2005: 47)

An antenna, which is usually made of a coil of wire, is used to transmit and receive radio frequency signals that permit the tag to exchange data with a RFID reader (Bhuptani *et al.*, 2005: 47). Antennae can be built into door frames, mounted on ceilings, embedded into floors, located above shelving or stocking locations, and strategically located throughout a facility to create a network of checkpoints for increased visibility.

3.5.4 RFID Reader

Figure 6: Two Typical Passive RFID Readers on the left and Active RFID Reader on the right (Bhuptani *et al.*, 2005: 44)

RFID readers, also known as interrogators, are sophisticated key components of an RFID system. A reader can be either a handheld or stationary device. A reader is capable of automatically recognising and distinguishing all the RF tags within its reading field. This capability allows the RFID reader to simultaneously process all the data and provide for efficient material handling, packaging, and sorting of inventory (Finkenzeller, 2003:309; Sandip, 2005: 20). Not only can RFID readers track tagged items and equipment, but they can also be used to track livestock and even human beings such as patients in a hospital. Tags must be compatible with the reader protocol and support the frequency of the reader as well as be within the active field of the reader. However, there is a limit to how many tags a reader can successfully interrogate within the field (Sandip, 2005: 20). In addition to reading the data stored in a tag, a reader also energises passive and semi-passive tags in its electromagnetic field, and may be equipped with write capabilities to overwrite data on read-write tags.

3.5.5 Software, Middleware, and Host Application

While the previous section described the different types of RFID tags and readers, the following section explores the various software systems that are used to integrate RFID components into useful RFID systems.

A number of functions are programmed into RFID system software to allow the tag and reader to communicate. System software typically provides the tag and reader with read-write capabilities (Bhuptani *et al.*, 2005: 50). In cases where a large

number of tags need to be read simultaneously, which is often the case in retail applications, the software has an anti-collision function that keeps the tags from responding all at once. Readers can also be equipped with error detection functions to reduce the risk of incomplete or duplicate data. In some instances the software may even be fitted with encryption and authentication functions for security purposes (Bhuptani *et al.*, 2005: 50).

RFID middleware is a software platform that enables data exchange from a RFID reader or network of readers to host application software, such as warehouse management systems (WMS), enterprise resource planning (ERP) systems and databases (Bhuptani *et al.*, 2005: 52). Middleware connects the RFID reader and data processing software to business applications such as enterprise inventory or identification management systems. Middleware is designed to process RFID functions and present them to business applications in such a way that they can be processed further by those applications (Sandip, 2005:40). In addition, a middleware platform provides the operating system, data repository, and processing algorithms that convert multiple tag inputs into visible tracking or identification data (Bhuptani *et al.*, 2005: 52). Middleware can be managed by personnel within a company using RFID or be contracted out to an IT service provider. Moreover, RFID middleware also monitors the status of the reader, which is considered to be a particularly important function in environments where multiple readers are distributed across different locations and where manual monitoring is not practical (Bhuptani *et al.*, 2005: 52).

Finally, the host application software receives the data sent from the middleware (Bhuptani *et al.*, 2005: 53). Host application software is not necessarily RFID-specific, and is often retail management or inventory control software that is already in use. However, since RFID systems generate a lot of new data, some previously existing host applications may need to be modified to receive this data since they may lack a fully defined air interface protocol (Bhuptani *et al.*, 2005: 53).

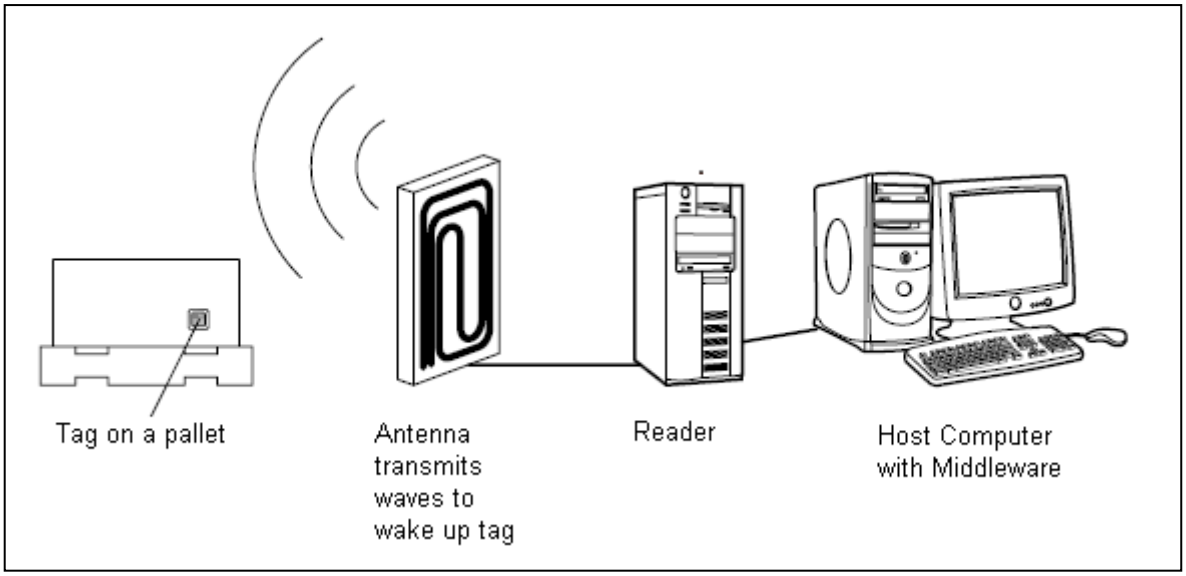

Figure 7: Illustrates the various building blocks which constitute an RFID system (Sweeney, 2005: 78)

3.6 RFID Standardisation

RFID technology requires standards to ensure that it can be universally assimilated into business applications. RFID can dramatically change the way companies do business, but standards are required to ensure that information is shared appropriately and effectively (Davison, 2005). According to IDTechEx (2004), one of the major factors restricting the development of RFID technology is the disunity of RFID standards. Currently, the two major standards are International Standards Organization (ISO) and EPCglobal (previously known as Auto-ID). These standards deal with numerous issues including (Finkenzeller, 2003:229):

- Air Interface Protocol: The way tags and readers communicate
- Data content: Organising of data
- Conformance: Tests that are designed to ensure products conform to a standard
- Applications: How applications are used.

3.6.1 EPCglobal

EPCglobal is a global RFID organisation and is in charge of establishing Electronic Product Code (EPC) standards, previously known as Auto-ID (Sandip, 2005: 200). The organisation is a joint venture between European Article Numbering Council

(EAN) and the Uniform Code Council (UCC) to support the EPC Network as the standard for automatic identification of items in retail (Sandip, 2005: 200). These standards offer the potential for increased efficiency and accuracy through automation, tracking and security through improved visibility, and collaboration by providing a global standard framework for information exchange.

The purpose of EPCglobal is to enable trading partners to minimise shrinkage and shortages, accelerate order processing and increase responsiveness to consumer demand by enabling the flow of real-time information about goods within the retail sector. Efficiency in handling physical goods during processes such as receiving, counting, sorting, and shipping is improved (Sandip, 2005: 200).

Below is one of many examples of a 96-bit EPC data structure. It consists of the Header, in which the first 2 bits must contain zeros, the EPC Manager (manufacturer number), the Object Class (identifies the product), and the factory or end-user programmable Serial Number (a uniquely assigned number for each individual item).

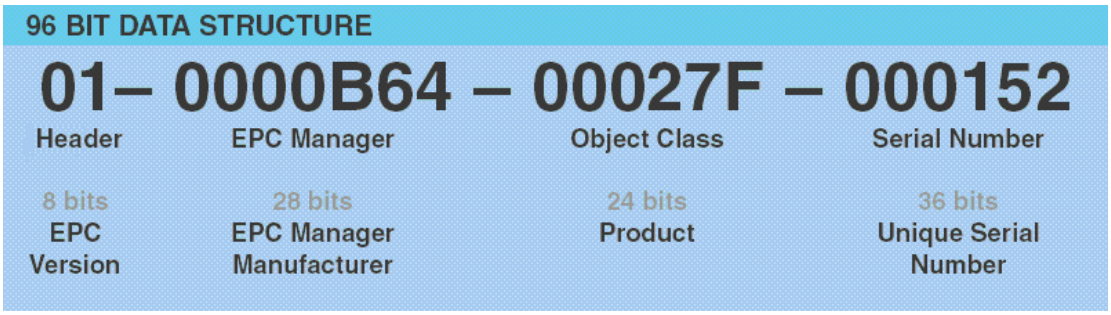

Figure 8: 96-bit EPC data structure (Sandip, 2005: 202)

3.6.2 International Organization for Standardization (ISO)

The ISO is a non-governmental organisation that is linked to a network of national standards institutes from over 145 countries. One member per country is represented at the ISO, with a Central Secretariat in Geneva, Switzerland, that coordinates the system (Sandip, 2005: 205). ISO holds a special position between the public and private sectors. Some of its member institutes are part of the government structure of their countries or are mandated by their government, while other members are from the private sector, having been set up by national partnership of industry association (Bhuptani *et al.*, 2005: 72). ISO has published more than 15000 International

Standards in a multitude of areas, including RFID. Some of the ISO standards relating to RFID technology are the following (Bhuptani *et al.*, 2005: 72; Finkenzeller, 2003: 229):

- ISO 11784, 11785, 14223: contain specifications for RFID tags used in animal tracking.
- ISO 10536, 14443, 15693: contain specifications for RFID tags used in proximity and vicinity cards.
- ISO 10374: contain specifications for RFID tags used on freight containers (for example, rail and ship).
- ISO 15961, 15962, 15963: contain specifications for RFID tags used in item management, including data protocol, application interface, data encoding rules, logical memory functions and unique identification for tags.
- ISO 18000 (1-6) series: contain specifications for RFID tags used in item management, which address the parameters for Air Interface Communications for globally accepted frequencies such as 135KHz, 13.56MHz, UHF band, 2.45GHz and 5.8GHz.

3.7 Frequencies (LH, HF, UHF)

Since RFID uses electromagnetic radio waves, its effectiveness is subject to the same physical laws governing any other radio frequency operating device (Finkenzeller, 2003:30; Sandip, 2005:2; Shepard, 2004:61). The distance between the radio frequency interrogator antennae, the corresponding RFID tag and the frequency are all directly interrelated.

Difference between low (LF), high (HF), very-high (VHF), ultra-high (UHF) and microwave frequencies

Just as a radio must be tuned into different frequencies in order to receive different stations, RFID tags and readers must both be tuned to the same frequency in order to communicate. The most regularly used frequencies among RFID systems are low (around 125KHz), high (13.56MHz), ultra-high (860MHz to 960MHz) and microwave (2.4GHz to 5.8GHz) (Dipert, 2004). Radio waves behave in a different way at different frequencies; therefore, it is important to select the best frequency for the correct RFID application, since each behaves differently. For instance, the low

frequency tags are useful for close range, and are cheaper than HF and UHF tags. UHF tags, on the other hand, are ideal for scanning objects as they pass through a bay door, since they offer a better range, but usually require more power and require a clear path between tag and reader (Sandip, 2005: 4; Finkenzeller, 2003:30).

Every country has different RFID operating frequencies. The United States uses 915 MHz, Europe uses 868 MHz, and Japan currently does not allow any use of the UHF spectrum of RFID.

Frequency	LF	HF	VHF	UHF	Microwave
Frequency range	30-300KHz	3-30MHz	30-300MHz	300MHz-1GHz	1GHz>
Reflection/Nulling	None	Low	High	Higher	Highest
Electrical interference	None	High	Low	Lower	None
Distance	< 2m, typical 1cm-1.5m	< 1m, typical 1cm-0.7m	1-100m, typical 1-3m	1-100m, typical 1-3m	1-300m, typical 1-20m
Data rate	1-10KB/s	1-3KB/s	1-20KB/s	1KB-10MB/s	1KB-10+MB/s

Table 3: Spectrum Characteristics (Sandip, 2005:4; Eagleson, 2001)

There is absolutely no health risk associated with RFID radio waves since RFID utilises the low-end of the electromagnetic spectrum. RFID waves are in fact similar to normal radio waves (Finkenzeller, 2003: 161).

Frequency Range	LF 125KHz	HF 13.56MHz	UFH 868-915MHz	Microwave 2.45 & 5.8GHz
Typical Max Read Range (Passive Tags)	<0.46m	Approximately 0.9 – 1.5m	Approximately 4.6 – 6m	Approximately 0.9 – 1.5m
General Characteristics	Relatively expensive, even at high volumes. Low frequency requires a longer, more expensive copper antenna.	Less expensive than inductive LF tags. Relatively short read range and slow data rates when compared to higher frequencies. Best suited for application that	In large volumes, UHF tags have the potential for being cheaper than LF and HF tags due to recent advances in integrated chip design. Offers good	Characteristics similar to the UHF tag, but with faster read rates. A drawback to this band is that microwave transmissions are most susceptible to

	Additionally, inductive tags are more expensive than capacitative tags. Least susceptible to performance degradations from metal and liquids, though read range is very short.	do not require long range reading of multiple tags.	balance between range and performance, especially for reading multiple tags.	performance degradations due to metal and liquids, among other materials. Offers the most directional signal; ideal for certain application.
Tag Power Source	Generally passive tags only, using inductive coupling	Generally passive tags only, using inductive or capacitative coupling	Active tags with integral battery or passive tags using capacitative, E-field coupling	Active tags with integral battery or passive tags using capacitative, E-field coupling
Typical Application Today	Access control, animal tracking, vehicle, immobilisers, POS applications including SpeedPass	Smart cards, item-level tracking including baggage handling (non-US), libraries	Pallet tracking, electronic toll collection, baggage handling (US)	Supply chain management, electronic toll collections
Notes	Largest install base due to the mature nature of low frequency, inductive transponders	Currently the most widely available high frequency worldwide, due mainly to the relatively wide adoption of smart cards	Japan does not allow transmission in this band. Europe allows 868MHz. US permits operation at 915MHz, but at higher power levels	
Data Transfer Rate	Slower ----------→ Faster			
Ability to read near metal or wet surfaces	Better ----------→ Worse			
Passive Tag Size	Larger ----------→ Smaller			

Table 4: Tag Performance at Various Frequencies (Yeung *et al.*, 2003; Finkenzeller, 2003:161; Shepard, 2004:63)

The two main frequencies used in the tracking of pallet sized and smaller items are 13.56 MHz high and the 915 MHz Ultra high frequencies. For effective RFID implementation there needs to be a considerable effort made to determine what type of application the user intends to implement. The application can steer stakeholders of a project to allocate resources, review business practices for implementation techniques, and evaluate specific needs of the technology.

Regional Map of Frequencies

Below is a map showing the frequencies used by major markets such as the United States and Canada, EU countries, Japan, Australia, New Zealand and South Africa.

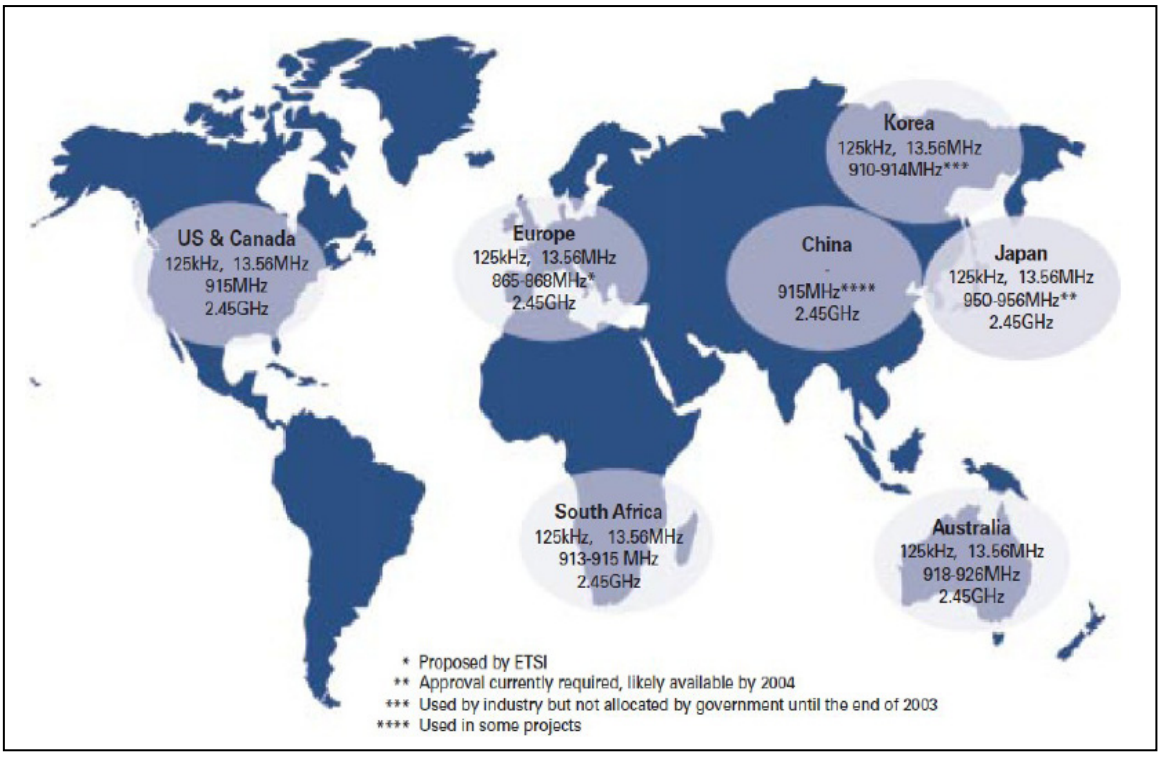

Figure 9: International RFID Frequency Regulations (Sandip, 2005:5)

3.8 Application of RFID Technology

RFID technology is used in many sectors of industry and commerce. The following section describes the most important areas of application through examples of where and how RFID systems are applied.

3.8.1 Transportation

The transportation industry is one of the leading users of RFID technology, having identified and implemented numerous applications. RFID applications in transportation include railroad car management, traffic management, tolls and fees, fare collection, equipment identification, fleet management, solid waste hauling, and fuel dispensing (Finkenzeller, 2003:361; Shepard, 2004:134). When a vehicle passes through an express toll lane an RFID tag alerts the tag reader that someone has passed through the toll and the reader then identifies the driver and debits the required toll fee from a prepaid value stored on the tag. Alternatively the system could be linked to a monthly billing system (Sandip, 2005:101).

Petrol stations have also experimented with automatic RFID payment technology. A customer having just refuelled a vehicle could simply wave his or her RFID tag across a reader in order to process payment. The system would then be linked to the customer's account that would be debited like any other financial transaction.

3.8.2 Logistics

The key benefits of embedded tags on cases, cartons and pallets are the ability to read the entire contents of mixed pallets, all at once, during material handling operations such as truck loading or unloading (Finkenzeller, 2003:363). Managing pallets and other returnable transit containers with RFID is one of the most dramatic cost-saving opportunities that this technology can provide. Many returnable containers are never brought back from customer sites after shipment, forcing companies to carry excess inventory to ensure adequate supplies of shipping materials where they are needed. Identifying returnable containers with fixed tags enables companies to augment their legacy barcode shipping applications by automatically recording materials shipped to customers (Raza, Bradshaw and Hague, 1999:2). Companies can then find their own

pallets in shipping yards or docks stacked with thousands of items belonging to hundreds of companies.

3.8.3 Security

Many businesses use RFID to control access to hotels and business facilities by attaching a tag to an employee's room card or ID badge (Sandip, 2005:100; Shepard, 2004:133). Such technology ensures that only authorised persons are allowed access to particular rooms or entrances. This application is also becoming more common in nursing homes and hospitals where the management and tracking of individuals is very important, and alarms are more discrete (Sandip, 2005:104).

Other security features include RFID chips that can be embedded into car keys. Only if the appropriate key together with its tag is used to start the vehicle will the vehicle start.

3.8.4 Libraries and Video Stores

Many libraries around the world have implemented RFID to increase the efficiency of administering loan material. Tags are embedded in books, made invisible to customers, and counter personnel are then able to check many books in or out in seconds without manually handling each item (Sandip, 2005:100; Shepard, 2004:150). RFID tags can also be used for theft detection, similar to anti-shoplifting technology currently used by retailers. Librarians using portable RFID readers can take inventory and find misfiled books simply by walking down the passageway of bookshelves, and the reader can automatically detect missing materials and alert the operator (Sandip, 2005:100).

Video stores are using RFID for similar applications. Readers are placed at the checkout, return bins, and doorways to record transactions and detect shoplifted items automatically. These library and video store operations are essentially inventory management applications that can be adapted for use in many other industries, such as retail.

3.8.5 Medical Applications

Medical applications include allowing restricted access and tracking patients and guest with authorised wristbands through hospitals. For pediatrics only staff or parents may be permitted to take infants or children from specific areas or the confines of a ward. In the UK, RFID applications have eliminated opportunities for "baby-snatching" or kidnapping to occur on hospital grounds (Finkenzeller, 2003:392).

Hospitals can also use RFID to track medication dispensing, laboratory samples, and blood bags - much as barcodes are used today. RFID saves time and improves accuracy because it automatically records all item movements and does not require human intervention to scan a barcode or record data on a form.

3.8.6 Pharmaceutical

RFID tags are embedded in prescription bottles used by blind people. Patients in the programme are given compact reading devices that are activated when a prescription bottle is held close to the device. The reader identifies the contents and then using text-to-speech conversion software, reads the drug contents to the patient. This technology helps ensure that patients take the correct medication (Finkenzeller, 2003:392). Other information such as dosage instructions and drug interaction warnings can also be encoded.

Pharmaceutical companies can use RFID to manage the movement of medication and containers through assembly and packaging lines to ensure medicines are put into correctly labelled packages. In addition to controlling production flow, this type of system can automatically build a paperless audit trail to provide a highly integrated and accountable supply chain.

3.8.7 Warehousing

Workers scan shelves and bins with an RFID reader that automatically detects the storage location of the required items. The system can also detect items that are stored in the wrong location and alert operators to the problem (Raza *et al.*, 1999:2). Using RFID for these applications enables items to "self-report" their locations, rather than

requiring human intervention to find them, thus reducing errors, saving labour and lowering costs (Sandip, 2005:95).

3.8.8 Manufacturing

RFID technology is used to enable automated manufacturing processes such as unattended work-in-process tracking and can be integrated with control systems to route items automatically through assembly processes. Moreover, product serial numbers and other identification data can be securely encoded in read-only memory during the manufacturing of personal computers to provide lifetime tracking and product authentication. Some manufacturers take advantage of this functionality to verify eligibility for returns and warranty repairs and detect counterfeit products. Maintenance history can be stored on the tag and updated whenever service is performed (Sandip, 2005:92).

3.9 Conclusion

RFID makes use of radio transmission to recognise, categorise, locate and track objects. RFID systems consist of readers, tags, software/middleware and host applications for storage and management of data. RFID tags are attached to products and can be read when they enter a reader's antenna field. Since RFID systems use radio waves, there is no need for contact or direct line-of-sight between readers and tags. Tags can be powered by the antenna field of the reader, an external field or by an internal battery.

A standardised process is imperative for the large scale deployment of RFID systems to ensure guaranteed component compatibility and open competition of suppliers thus reducing prices and dependencies. The ISO standard and the EPCglobal standard are the most prominent ones.

RFID is a complex and versatile technology that has wide application. While it is technically complex and involves various sub-systems, it offers greater versatility than conventional barcode technology.

Chapter 4

Diffusion of Innovation

The previous chapter presented the fundamentals and applications of RFID technology. This chapter explores the issues that influence the diffusion of innovation as it relates to the adoption of a new innovation, such as RFID. It seeks to identify factors facilitating and inhibiting such adoption. Further, supplementary theories and models are investigated in addition to the diffusion of innovation theory, in order to gain an understanding of the factors that might impact the uptake of a new technology such as RFID.

4.1 Introduction

When an innovation such as RFID is introduced, no matter how attractive the new innovation may seem, there are various obstacles and barriers that must be overcome in order for the innovation to be accepted and adopted. In this chapter, different models and theories are investigated to elaborate on the reasons an individual or group of people decide to adopt or not adopt an innovation such as RFID technology. These reasons can be viewed as the barriers and obstacles to an innovation.

Diffusion of innovation is the fundamental theory that explains how a new idea or innovation is spread within a social system, which consists of individuals, informal groups, organisations and subsystems (Rogers, 2003). This cogent set of conceptual generalisations is usually referred to as diffusion of innovation theory. The objective is to explain the gradual adaptation of an innovation. The theory includes theoretical generalisations about how and through what media an innovation is communicated, the characteristics of innovations (constructs), the decision process that leads to adoption, and the characteristics of adopters. Additionally, there is an increasing theoretical concern about the effects of innovation adoption (Rogers, 2003).

There are several theories and models that support and supplement Rogers work by investigating the social and technology aspects relating to the diffusion of innovation. These theories and models include:

- Adoption of information technology innovation theory (Moore and Benbasat, 1991)
- Theory of reasoned action (Fishbein and Ajzen, 1975)
- Social cognitive theory (Bandura, 1977; Bandura, 1986)
- Technology acceptance model (Venkatesh, Morris, Davis and Davis, 2003)
- Theory of planned behaviour (Ajzen, 1991)
- Model of personal computer utilization (Thompson, Higgins and Howell, 1991)

Concerning the factors influencing adoption, there are many studies classifying them. But the nature of technology adoption can be grouped into two main influential

categories, and they are organisational-level technology adoption and individual-level technology adoption. The organisational-level technology adoption refers to organisational factors that influence technology adoption, such as organisation size and readiness (Tornatzky and Fleischer, 1990; Brown and Russell, 2007). Diffusion of innovation theory and adoption of information technology innovation theory is referred to as innovation characteristics in some studies of organisational adoption (Premkumar and Roberts, 1999). Individual-level technology adoption refers to factors that influence the adoption of technology by an individual. The other five theories and models mentioned above fall under individual-level technology adoption. Organisational decisions on technology adoption are often heavily dependent on individuals such as CEOs or CIOs, hence the need to address individual-level technology adoption.

This chapter will explore each of these theories in an attempt to provide an understanding of their impact on the acceptance of an innovation such as RFID.

4.2 Diffusion of Innovation

Innovation is "an idea, practice or object that is perceived as new by an individual or its audience" (Rogers, 2003:11). An innovation is not an invention, according to Vuarin and Rodriguez (1994:15): it is "doing something which did not exist before in a particular territory or technical area". According to Rogers (2003:5), "Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system". This existence of a social system is of great importance when considering the uptake of RFID generally and the relative rate of adoption within the retail sector in South Africa. Thus we can conclude that diffusion of innovation is a social sciences theory for how and why new ideas spread through different cultures.

Innovation diffusion research has been characterised as rational and interpretive (Beynon-Davis and Williams, 2003). One of the most widely used rational theories is Rogers' (2003) diffusion of innovations theory, which represents the rate of adoption and the stages through which one has to go before adopting an innovation. Theories such as this aim to trace and explain the path of an innovation's acceptance through a given social system, over time. Although it is acknowledged that social influences

can impede or facilitate the process, the emphasis tends to fall on the innovation itself. Rogers' theory has been criticised for its linearity, and not taking into account the complexity of information technologies (Lyytinen and Damsgaard, 2001). It can be argued that innovation diffusion is an "unstructured emergent phenomenon" (Baskerville and Pries-Heje, 2001:187) and is too complex to be expressed in a theory. In contrast, interpretive approaches, such as those concerned with the social construction of technology (Bijker and Law, 1994), emphasise the way that technologies are "configured" throughout the process of diffusion by various members, or relevant social groups, such as professional associations.

4.2.1 Social System

As mentioned, the social system is an intrinsic part of innovation diffusion theory. A social system is defined as a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. The members or units of a social system may be individuals, informal groups, organisations, and/ or subsystems. All members cooperate at least to the extent of seeking to solve a common problem in order to reach a mutual goal, and sharing a common objective binds the system together. The social structure affects the innovation's diffusion in several ways:

- Social and communication structure: patterned arrangements of the units in a system
- System norms: norms are established behaviour patterns for the members of a social system
- Roles of opinion leaders and change agents: opinion leadership is the degree to which an individual is able to influence other individual's attitudes or overt behaviour informally in a desired way with relative frequency
- Types of innovation decisions: optional innovation-decision, collective innovation-decision, authority innovation-decision; contingent innovation-decision
- The consequences of innovation: desirable vs. undesirable, direct vs. indirect, anticipated vs. unanticipated

4.2.2 Categories of different types of adopters

Individuals are seen as possessing different degrees of willingness to adopt innovations and thus it is generally observed that the portion of the population adopting an innovation is approximately normally distributed over time (Rogers, 2003). Breaking this normal distribution into segments leads to the segregation of individuals into the following five categories of individual innovativeness (from earliest to latest adopters): innovators, early adopters, early majority, late majority, laggards (Rogers, 2003). Members of each category typically possess certain distinguishing characteristics, as shown below.

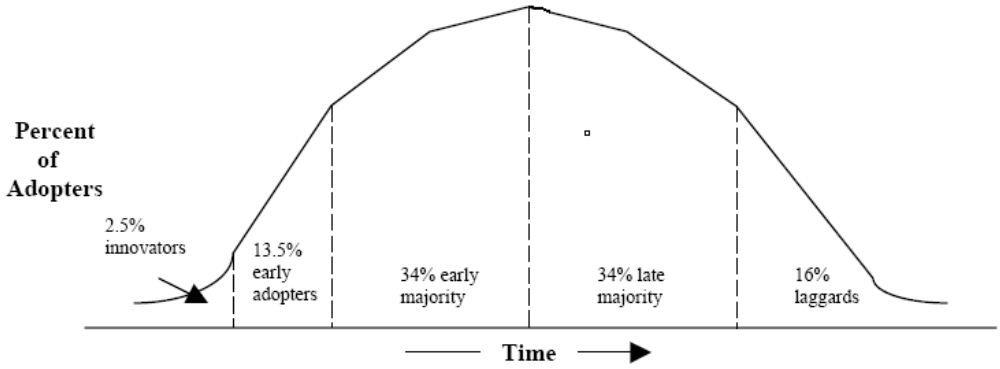

Figure 10: Innovation Adoption Model (Rogers, 2003)

Innovators are more global oriented, well-informed, have superior knowledge, and are of higher socioeconomic status than later adopters (Rogers, 2003). One of the most important characteristics of the first segment of a population to adopt an innovation, the innovators, is that they require a shorter adoption period than any other category. Rogers (2003) identifies several additional characteristics dominant in the following type:

- Innovators, also known as risk takers, are the first 2.5 percent of individuals in a system to adopt an innovation. Venturesomeness is almost an obsession with innovators. Their interest in new ideas leads them out of a local circle of peer networks and into more broad social relationships. Communication patterns and friendships among a clique of innovators are common, even though the geographical distance between the innovators might be considerable (Rogers, 2003). Being an innovator has several prerequisites.

Control of substantial financial resources is helpful to absorb the possible loss from an unprofitable innovation. The ability to understand and apply complex technical knowledge is also needed. The innovator must be able to cope with a high degree of uncertainty about an innovation at the time of adoption (Rogers, 2003). While an innovator might not be respected by the other members of a social system, they play an important role in the diffusion process, that of launching the new idea in the system by importing the innovation from outside of the system's boundaries (Rogers, 2003). Thus, the innovator plays a gatekeeping role in the flow of new ideas into a system. To illustrate this, there is currently innovative research being conducted around banknotes that contain RFID embedded tags. While there may be obvious benefits to being able to monitor and record financial transactions via the embedded tags, privacy and security concerns have negatively impacted progress towards the adoption of this technology (Avoine, 2004).

- Early adopters are the next 13.5 percent of the individuals in a system to adopt an innovation. Early adopters are a more integrated part of the local system than are innovators. Whereas innovators are globally oriented, early adopters are locally oriented. This adopter category, more than any other, has the greatest degree of opinion leadership in most systems (Rogers, 2003). Potential adopters look to early adopters for advice and information about the innovation. This adopter category is generally sought by change agents as a local missionary for speeding the diffusion process. Because early adopters are not too far ahead of the average individual in innovativeness, they serve as a role-model for many other members of a social system (Rogers, 2003). The early adopter is respected by his or her peers, and is the embodiment of successful, discrete use of new ideas. The early adopter knows that to earn the esteem of their colleagues and to maintain a central position in the communication networks of the system, they must make judicious innovation decisions. The early adopter decreases uncertainty about a new idea by adopting it, and then conveying a subjective evaluation of the innovation to near-peers through interpersonal networks (Rogers, 2003). According to Fenn, Cearley, Valdes, Tully, Basso, Uzureau, Dulaney, Fiering, Jones, Phifer, Claunch, Knox, Smith, Willis, Maio, Sholer, Smith, Cramoysan, Drakos,

Davison, Smith, Reynolds, McGuckin, Blechar, McCoy, Norton, Andrews, Driver, Austin, Schulte, Chamberlin and Ball (2006), RFID technology falls under this category, where only a few organisations around the world are currently making use of this technology in their business, such as Wal-Mart in the US, Marks & Spencer in the UK, Metro in Germany and Carrefour in France.

- The early majority are the next 34 percent of individuals in a system to adopt an innovation. The early majority adopt new ideas just before the average member of a system. They interact frequently with their peers, but seldom hold positions of opinion leadership in a system (Rogers, 2003). The early majority's unique position between the very early and the relatively late to adopt makes them an important link in the diffusion process. They provide interconnectedness in the system's interpersonal networks (Rogers, 2003). The early majority are one of the two most numerous adopter categories, making up one-third of the members of a system. The early majority may deliberate for some time before completely adopting a new idea. "Be not the first by which the new is tried, nor the last to lay the old aside," fits the thinking of the early majority (Rogers, 2003). They follow with deliberate willingness in adopting innovations, but seldom lead. Organisations currently utilising Voice over Internet Protocol (VoIP) technology are considered early majorities (Fenn *et al.*, 2006), as many organisations starting to use VoIP technology internally for communication between individuals and departments.

- The late majority are the next 34 percent of the individuals in a system to adopt an innovation. The late majority adopt new ideas just after the average member of a system. Like the early majority, the late majority make up one-third of the members of a system. Adoption may be the result of increasing network pressures from peers. Innovations are approached with a skeptical and cautious air, and the late majority do not adopt until most others in their system have done so (Rogers, 2003). The weight of system norms must definitely favour an innovation before the late majority are convinced. The

pressure of peers is necessary to motivate adoption. Their relatively scarce resources mean that most of the uncertainty about a new idea must be removed before the late majority feel that it is safe to adopt (Rogers, 2003). Many cell phone manufactures are now manufacturing 3G-enabled phones for ordinary users as a default feature, resulting in an increasing number of users making use of 3G technology for easy access of information through their cell phones, particularly in developed countries, such as the United States of America and the United Kingdom, where utilising costs are low.

- Laggards constitute the last 16 percent of the individuals in a system to adopt an innovation. They possess almost no opinion leadership. Laggards are the most locally oriented in their outlook of all adopter categories, and many are almost isolated in the social networks of their system (Rogers, 2003). The point of reference for the laggard is the past. Decisions are often made in terms of what has been done previously. Laggards tend to be suspicious of innovations and change agents (Rogers, 2003). Resistance to innovations on the part of laggards may be entirely rational from the laggard's viewpoint, as their resources are limited and they must be certain that a new idea will not fail before they can adopt.

4.2.3 Time associated with the rate of adoption

When considering the adoption of an innovation, the time variable is closely related to the rate of adoption by various adopters. This can be shown when the adoption curve is converted to a cumulative percent curve, a characteristic S curve, as shown in Figure 11 below. The curve represents the rate of adoption of the innovation within the population over time (Rogers, 2003). The rate of adoption of an innovation is impacted by five factors: relative advantage, compatibility, trialability, observability, and complexity (Rogers, 2003). The first four factors are generally positively correlated with rate of adoption, while the last factor, complexity, is generally negatively correlated with rate of adoption (Rogers, 2003). Adopters tend to implement and use an innovation if it provides them with a relative advantage and is better than the current technology in use at the time. As discussed in Chapter 3, the

use of RFID technology within the retail supply chain may arguably provide retailers with a competitive advantage over traditional barcode technology, in that:

- data is more accurate and up-to-date
- there are lower labour expenses
- shelf shortages are reduced
- shrinkage is reduced
- inventories may be managed efficiently
- customers might experience a more satisfying shopping experience.

The actual rate of adoption is governed by both the rate at which an innovation 'takes-off' and the rate of later growth. Low cost innovations may experience a rapid uptake while innovations whose value increases with widespread adoption might have faster late stage growth. RFID is considered to be a high cost technology, which according to Rogers' adoption theory could result in its slow uptake within the retail sector. Innovation adoption rates can, however, be impacted by other phenomena. For instance, the adaptation of technology to individual needs can change the nature of the innovation over time. In addition, an innovation can impact the adoption rate of an existing innovation and path dependence may lock potentially inferior technologies in place.

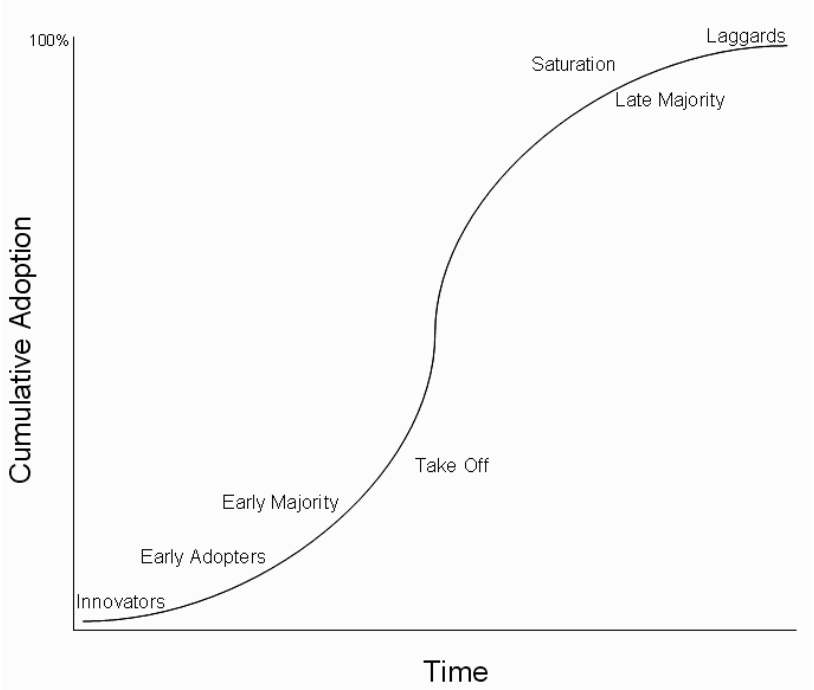

Figure 11: Diffusion Process (Rogers, 2003)

According to Rogers (2003), there are only a few innovators are willing to adopt the innovation at the early stage. However, as these innovators begin to communicate about the innovation to their peers, it encourages early adopters to begin implementing the innovation, followed by early majorities. This leads to a heavy rate of adoption. After this accelerated growth, diffusion tapers off to include only a small number of 'late majorities' (Rogers, 2003). The current status of the application of RFID in the retail sector is thought to be following Rogers (2003) diffusion process, with only a minority of major retailers, such as Wal-Mart and Metro, willing to adopt RFID technology at the moment, while many organisations might still be waiting for the technology to mature and be accepted by all customers.

4.2.4 The Adoption Process

Rogers (2003) defines the adoption process as the "mental process through which an individual passes from first hearing about an innovation to final adoption". He contrasts this with the diffusion process which he suggests is the "spread of a new idea from its source of invention or creation to its ultimate users or adopters". Rogers differentiates the adoption process from the diffusion process in that the diffusion process occurs within society, as a group process, whereas the adoption process pertains to an individual. According to Rogers (2003), the adoption process can be broken down into five stages. These are:

- awareness stage
- interest stage
- evaluation stage
- trial stage
- adoption stage.

During the awareness stage, the individual is aware of the innovation, but requires complete information about it. At the interest or information stage, the individual becomes interested in the innovation and looks for further information about it. At the evaluation stage, the individual mentally applies the innovation to his or her condition and then decides whether or not to try it. During the trial stage, the individual utilises the innovation. At the adoption stage, the individual decides to carry on using the innovation (Rogers, 2003). It is believed that RFID technology is currently in its awareness and interest stage for the majority of retailers, where there is an awareness

of the technology and interest in the advantages of its application. Retailers require further research into the technology prior to progressing to the evaluation, trial and adoption stages. Early adopters such as Wal-Mart and Metro are currently in their trial and adoption phases.

4.2.5 Factors affecting the rate of adoption of an innovation

As discussed previously, a centerpiece of diffusion theory relates to the perception of innovations by potential adopters. Rogers (2003) describes the characteristics of an innovation in terms of its perceived attributes. According to Rogers (2003), and other rational diffusion theorists such as Moore and Benbasat (1991) and Agarwal and Prasad (1997), there are certain characteristics of innovations that affect their rate of adoption. Rogers' perceived characteristics of innovations are detailed below:

- Relative Advantage: the degree to which an innovation is perceived as being better than the idea it supersedes. The degree of relative advantage may be measured in economic terms, but social prestige, convenience, and satisfaction are also important factors. It does not matter so much if an innovation has a great deal of objective advantage. What does matter is whether an individual perceives the innovation as advantageous. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption.
- Compatibility: the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters.
- Complexibility: the degree to which an innovation is perceived as relatively difficult to understand and use. New ideas that are simpler to understand are adopted more rapidly than innovations that require the adopter to develop new skills and understandings.
- Trialability: the degree to which an innovation may be experimented with on a limited basis. An innovation that is trialable represents less uncertainty to the individual who can benefit by experimenting with it prior to committing to it.
- Observability: the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt. Such visibility stimulates peer discussion of a new idea, as friends and neighbours of an adopter often request innovation-evaluation information about it.

Rogers (2003) stated that his theory was limited and might not always hold true due to its linearity. It can be argued that innovation diffusion is an 'unstructured emergent phenomenon' (Baskerville and Pries-Heje, 2001:187) and is too complex to be expressed in a step-like model. However, the model can still be used to track the general trend and social perceptions for new adoption. There are several distinct aspects about innovation diffusion research, including lack of prior knowledge about the innovation and the importance of attitude change and decision-making. Because an innovation is a new concept to the targeted audience, there is a "high degree of uncertainty in seeking information about, and deciding to adopt and implement an innovation".

To illustrate this in the context of RFID systems, one of the most prominent advantages recognised by the social group is the potential to improve business performance by increasing efficiency, especially in the retail sector, as a result, increasing in the rate of adoption. But on the other hand, compatibility and complexity is a major consideration when it comes to adopting RFID systems, given that the integration of RFID technology with existing systems is considered rather difficult, and requires RFID expertise. Thus a slow rate of adoption may be expected as compatibility and complexity are relatively high. As an example, Wal-Mart, a leader in the uptake of RFID technology, has experienced various difficulties such as technical hurdles, a relatively high cost, a lack of standards, a lack of education, and various social concerns. This has led to roll-out delays of RFID across its retail supply chain. Not surprisingly, individuals and organisations are viewing Wal-Mart's progress with much interest. As Wal-Mart navigates around adoption barriers, so will potential future adopters be able to learn from Wal-Mart's mistakes and experiences, which ultimately could lead to an increase in the rate of adoption of RFID.

4.2.6 Innovation-decision process

Rogers (2003) proposed that for any new idea to be implemented, an innovation-decision process must be executed. The innovation-decision process is the mental process through which an individual or other decision-making unit passes from first knowledge of an innovation to forming an attitude toward the innovation. This also involves the decision to adopt or reject an innovation, to implement an innovation,

and to confirm the decision to do so. An example of this process is that Wal-Mart passes on the knowledge about RFID technology and its practice in the retail supply chain to their supply chain providers, in order to alert them about such technology and the benefits of using it. Then Wal-Mart and their supply chain providers have to decide whether or not to adopt RFID technology in their business, and if both sides agreed to do so, they can then start to execute the plan. A final confirmation is then required from both parties after an investigation on the feasibility of the adoption of RFID technology in the supply chain process has been carried out. An individual seeks information at various stages in the innovation-decision process in order to decrease uncertainty about an innovation's expected consequences. Rogers (2003) suggests that this can be explained in a five-step process:

- Knowledge:
  Occurs when an individual is exposed to the innovation's existence and gains some understanding of how it functions
- Persuasion:
  Occurs when an individual forms a favourable or unfavourable attitude toward the innovation
- Decision:
  Occurs when an individual engages in activities that lead to a choice to adopt or reject the innovation
- Implementation:
  Occurs when an individual puts an innovation into use
- Confirmation:
  Occurs when an individual seeks reinforcement of an innovation decision or reverses the previous decision due to conflict

It should be noted that prior conditions affect the innovation-decision process. These prior conditions include: previous practice, perceived needs or problems, innovativeness, and norms of the social systems. Rogers (2003) suggests a model of diffusion of innovation as shown in Figure 12. It is used to determine the likelihood of adopting an innovation.

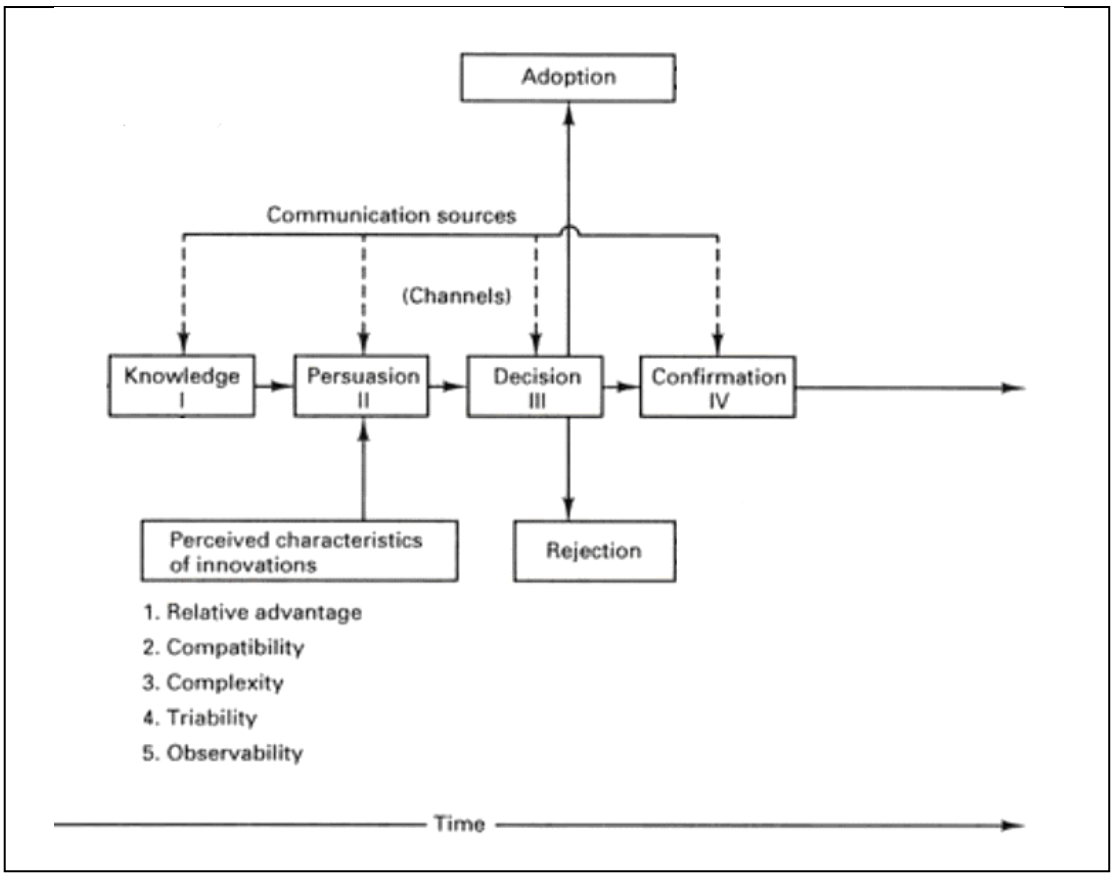

Figure 12: Subset derived from Diffusion of Innovation Model (Rogers, 2003)

Due to the versatility of the diffusion of innovation process, there has been an increase in research on the topic. A similarity found amongst the various research studies on the diffusion of innovation process is that the adoption process or the rate of diffusion can be charted on the S-shaped curve as shown in Figure 11.

Diffusion of technological innovation research came from Lehmann, Markman and Moreau (2001), who explored "the psychological processes underlying the individual consumer's adoption decision". Their research provides a wealth of information and correlation between prior product knowledge and attitudes towards and adoption of innovations. For example, consumers with low camera knowledge and high computer knowledge were the most likely to purchase a digital camera, whereas those with high camera knowledge and low computer knowledge were the least likely to purchase the digital camera. Their findings show that heavy research of the targeted audiences' prior knowledge in the innovation area can help marketers segment the audience in order for a more cost-effective and positive campaign (Lehmann *et al.*, 2001).

Further research on the relationship between perception of an innovation and actual adoption is addressed in a study by Chiasson and Lovato (2001) titled "Factors influencing the formation of a user's perceptions and use of a DSS software innovation". In their literature review, they acknowledged Rogers' (2003) work on the Perceived Characteristics of Innovation (PCIs), which was mentioned previously as: relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003).

When looking at technology change, relative advantage has the highest application value out of the five PCIs, because the innovation directly replaces a previous idea. This concept is key to the successful adoption of the new technology, because those who believe the new technology to be better than the previous one may also be more likely to adopt the innovation. As an example, an organisation might perceive barcode technology to be an older technology compared to RFID technology and so might be inclined to consider adopting RFID. It is important to note that the consequence of innovation might not all be positive and this needs to be borne in mind by those promoting the adoption of a new technology such as RFID.

Rogers (2003) stated that not all innovations are the same, and some elements of an innovation might weigh more heavily than others in influencing a potential adopter to accept or reject an innovation.

4.3 Adoption of Information Technology (IT) Innovation Theory

Moore *et al.* (1991), working in an Information Systems (IS) context, expanded upon the five factors impacting the adoption of innovations presented by Rogers (2003). They proposed the core constructs for the acceptance of an innovation to be:

- relative advantage
- ease of use (complexity)
- image
- visibility
- compatibility
- results demonstrability (observability)
- voluntariness of use.

Moore *et al.* (1991) proposed additional IT adoption factors:

- Image: the degree to which use of an innovation is perceived to enhance image or status in the social system.
- Visibility: the degree to which one can see others using the system in the organisation. Both employees and customers in Wal-Mart should be able to notice the difference after using RFID technology: Visual impact might reinsure usage of the technology.
- Voluntariness of use: the degree to which use of the innovation is perceived as being voluntary, or of free will. Any innovation, such as RFID, should not be forced on an individuals or an organisation.

In 2004, Wal-Mart started the adoption of RFID technology across their retail supply chains and since then, have gained the reputation as being the first major retailer to adopt RFID technology. Many organisations and individuals are watching Wal-Mart progress closely and as a result, Wal-Mart have gained the status as being the leader in the field of RFID adoption. It is interesting to note that Wal-Mart did force RFID on their suppliers by mandating that all goods supplied to Wal-Mart should be RFID tagged by the end of 2005.

Since the early application of diffusion of innovation theory to IS research, the theory has been applied and adapted in numerous ways. Research has, however, consistently found that technical compatibility, technical complexity, and relative advantage (perceived need) are important antecedents to the adoption of innovations leading to the generalised model presented below (Bradford and Florin, 2003; Crum, Premkumar and Ramamurthy, 1996):

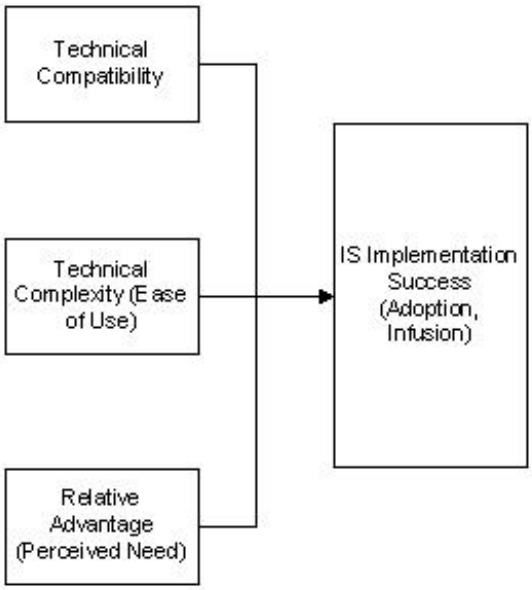

Figure 13: Information Systems diffusion variance model (Agarwal and Prasad, 1998; Bradford *et al.*, 2003; Cooper and Zmud, 1990; Crum *et al.*, 1996)

In addition, Fishbein and Ajzen's (1975: 302) Theory of Reasoned Action (TRA) and Davis' (1989: 320) Technology Acceptance Model (TAM) can also be used for analysing the diffusion of innovation in detail and to determine the reasons for individuals deciding to adopt or not to adopt an innovation.

4.4 Theory of Reasoned Action

The Theory of Reasoned Action (TRA) speculates that individual behaviour is driven by behavioural intentions, where behavioural intentions are a function of an individual's attitude toward the behaviour and subjective norms surrounding the performance of the behaviour (Fishbein *et al.*, 1975).

TRA is one of the most fundamental and influential theories of human behaviour. It has been used to predict a wide range of behaviours. Davis, Bagozzi and Warshaw

(1989) applied TRA to individual acceptance of technology and found that the variance explained was largely consistent with studies that have employed TRA in the context of other behaviours. The two core constructs are attitudes toward behaviour and subjective norms.

- Attitudes toward behaviour: an individual's positive or negative feelings about performing the target behaviour (Fishbein *et al.*, 1975: 302). For example, a Chief Information Officer's (CIO) personal feelings regarding RFID technology may ultimately influence the decision whether or not to adopt the technology.
- Subjective norm: the person's perception that most people who are important to him think he or she should or should not perform the behaviour in question (Davis, 1989: 320; Fishbein *et al.*, 1975: 302). As an example, a CIO may be negatively influenced to adopt RFID if his or her peers regard the technology as immature.

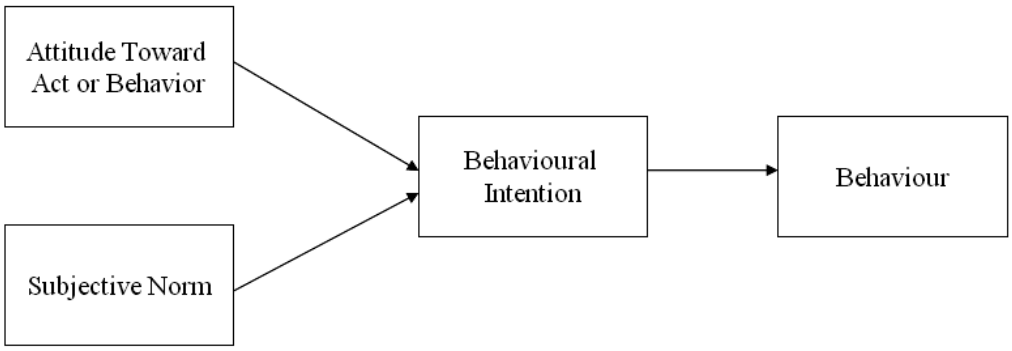

Figure 14: Theory of Reasoned Action (Fishbein *et al.*, 1975)

The TRA model has some limitations including a significant risk of confusing attitudes and norms since attitudes can often be reframed as norms and vice versa. A second limitation is the assumption that when someone forms an intention to act, they will be free to act without limitation. In practice, constraints such as limited ability, time, environmental or organisational limits, and unconscious habits such as avoiding the use of new technology, will limit the freedom to act. The Theory of Planned Behaviour (TPB) attempts to resolve this limitation, which will be discussed later.

4.5 Extended Social Cognitive Theory

Social Cognitive Theory (SCT) has also been used for explaining the behaviour of accepting an innovation. Social cognitive theory provides a framework for understanding, predicting, and changing human behaviour. The theory identifies human behaviour as an interaction of personal factors, behaviour, and the environment (Bandura, 1977; Bandura, 1986).

Compeau and Higgins (1995) applied and extended SCT to the context of computer utilisation (Compeau, Higgins and Huff, 1999). Compeau and Higgins' (1995) model studied computer use but the nature of the model and the underlying theory allow it to be extended to acceptance and use of information technology in general. Compeau and Higgins (1995) proposed five core constructs:

- Outcome Expectations (Personal): the personal consequences of the behaviour. Specifically, personal expectations deal with the individual esteem and sense of accomplishment.
- Outcome Expectations (Performance): the performance-related consequences of the behaviour. Specifically, performance expectations deal with job related outcomes.
- Self-efficacy: judgment of ability to use a technology such as RFID systems to accomplish a particular job or task.
- Affect: an individual's liking for a particular behaviour, such as how someone would feel working with an RFID systems.
- Anxiety: evoking anxious or emotional reactions when it comes to performing a behaviour such as using RFID technology. The degree of frustration experienced by the employee will determine the anxiety.

The above constructs explore how an individual's behaviour affects the uptake of an innovation, and as a result, influences the rate of adoption. As an example, in a retail store, if an employee perceives their productivity to be enhanced by the use of RFID, they are more likely to favour the adoption of RFID technology. This would undoubtedly impact the employee's attitude towards using technology such as RFID.

4.6 Technology Acceptance Model

The Technology Acceptance Model (TAM) is an adaptation of the TRA model and considered more suitable to the field of information systems. TAM postulates that perceived usefulness and perceived ease of use determine an individual's intention to use a system with the intention of serving as a mediator of actual system use. Perceived usefulness is also seen as being directly impacted by perceived ease of use (Venkatesh, Morris, Davis and Davis, 2003). An example would be the use of RFID technology in the retail sector. In order to gain technology acceptance, RFID technology must be simpler to use than current barcode technology, it must also increase the efficiency and effectiveness of the stock control process, and enhance the customer shopping experience.

Researchers have simplified TAM by removing the attitude construct found in TRA from the current specification (Venkatesh *et al.,* 2003). Attempts to extend TAM have generally taken one of three approaches: the introduction of factors from related models, the introduction of additional or alternative belief factors, the examination of antecedents of perceived usefulness and perceived ease of use (Wixom and Todd, 2005).

TRA and TAM, both of which have strong behavioural elements, assume that when someone forms an intention to act, they will be free to act without limitation. In practice, constraints such as limited ability, time, environmental or organisational limits, and unconscious habits, will limit the freedom to act.

TAM was designed to predict information technology acceptance and usage on the job (Davis, 1989: 320). This model has been widely applied to a diverse set of technologies and users. The core constructs are perceived usefulness, perceived ease of use, and subjective norm (which has been adapted from TRA).

- Perceived Usefulness: the degrees to which a person believes that using a particular system would enhance his or her job performance.
- Perceived Ease of Use: the degree to which a person believes that using a particular system would be free of effort.

The above two constructs are considered to be a key influence in the rate of RFID adoption. Organisations and individuals are very careful when deciding what new innovations to use. The first key factor is ease of use: if RFID technology is simple to use and requires little effort from the user, then both the employee and the customer are likely to be more accepting of the technology. The second key factor is technological usefulness: to what extent is RFID technology enhancing the supply chain process. The more useful the technology, the greater the possibility of its adoption.

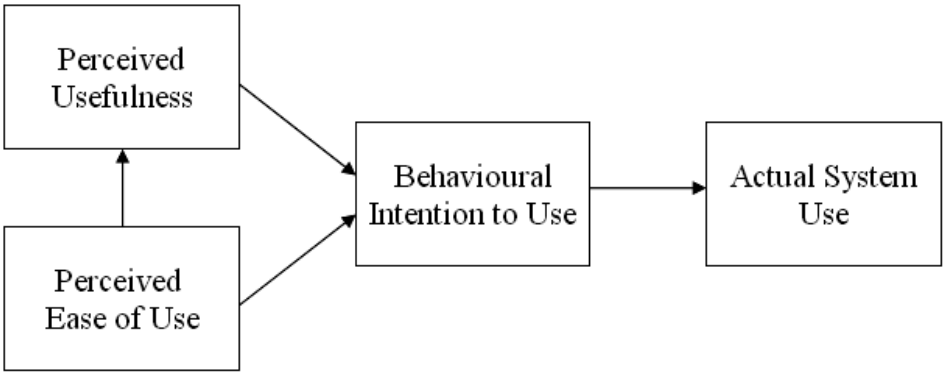

Figure 15: Technology Acceptance Model (Davis, 1989)

4.7 Theory of Planned Behaviour

Theory of Planned Behaviour (TPB) speculates that individual behaviour is driven by behavioural intentions, which are a function of an individual's attitude towards the behaviour; the subjective norms surrounding the performance of the behaviour; and the individual's perception of the ease with which the behaviour can be performed.

Theory of planned behaviour (TPB) was extended from TRA by adding the construct of perceived behavioural control. In TPB, perceived behavioural control is theorised to be an additional determinant of intention and behaviour. Ajzen (1991) presented a review of several studies that successfully used TPB to predict intention and behaviour in a wide variety of settings. TPB has been successfully applied to the understanding of individual acceptance and usage of many different technologies (Harrison, Mykytyn and Riemenschneider, 1997; Mathieson, 1991; Taylor and Todd, 1995b). A related model is the Decomposed Theory of Planned Behavior (DTPB). In terms of predicting intention, DTPB is identical to TPB. In contrast to TPB but

similar to TAM, DTPB "decomposes" attitude, subjective norm, and perceived behavioural control into their underlying belief structures within technology adoption contexts.

- Perceived Behavioural Control: the perceived ease or difficulty of performing the behaviour (Ajzen, 1991; 188). In the context of IS research, this is the perception of internal and external constraints on behaviour (Taylor *et al.*, 1995b: 149). The external constraints on the adoption of RFID would be the necessary technical knowledge to implement and use the systems, and the internal constrains would be the compatibility of an RFID system with the current systems in use.

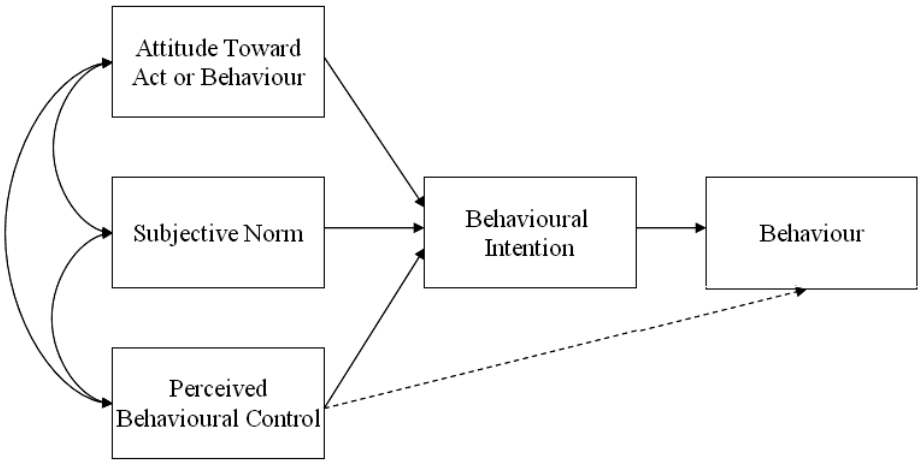

Figure 16: Theory of Planned Behavior (Ajzen, 1991)

4.8 Model of Personal Computer Utilization

A model of Personal Computer Utilization (MPCU), which is derived largely from Triandis's (1977) theory of human behaviour, presents a competing perspective to that proposed by TRA and TPB. Thompson, Higgins and Howell (1991) adapted and refined the Triandis's model for IS contexts and used the model to predict PC utilisation. However, the nature of the model makes it particularly suited to predict individual acceptance and use of a range of information technologies. Thompson *et al.,* (1991, 128-129) proposed the following core constructs:

- Job-fit: the extent to which an individual believes that using a technology can enhance the performance of his or her job, such as using RFID technology will speed up stock control process for the employees.

- Complexity: based on Rogers and Shoemaker (1971), the degree to which an innovation is perceived as relatively difficult to understand and use.
- Long-term Consequences: outcomes that have a pay-off in the future. As an example, by using RFID technology in Wal-Mart, retail stores are able to manage their stockroom more efficiently and effectively than barcode technology, as a result, better stock management in the long run.
- Affect Towards Use: based on Triandis (1977), affect toward use is "feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act". As mentioned above, customers may potentially enjoy fast check outs and reliable stock availability but at the same time may have concerns with privacy violations that might be embedded in the tag, which might cause some customers not to purchase any items in a retail store that is using RFID technology.
- Social Factors: derived from Triandis (1977), social factors are the individual's internalisation of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others in specific social situations.
- Facilitating Conditions: objective factors in the environment that observers agree make an act easy to accomplish. For example, returning items purchased online is facilitated when no fee is charged to return the item. In an IS context, provision of support for users of PCs may be one type of facilitating condition that can influence system utilisation. In an RFID-enabled retail store, there should be technical personnel with RFID knowledge to assist employees in the use of the system.

4.9 Organisational-level Technology Adoption

Organisational-level technology adoption focuses on understanding the adoption and diffusion process of the adopting organisation. Prior literature has identified many factors that are possible determinants of organisational adoption of a technology. According to Tornatzky *et al.* (1990) and Brown *et al.* (2007), organisational-level technology adoption can be grouped into three main contexts, namely technological, organisational, and environmental. Organisational context refer to those factors affecting the organisational structure that the organisation could adjust or change to

suit its changing environment. Technological context represents the perceived characteristics of the IT innovation. Finally, environmental context refer to those characteristics that create threats as well as opportunities for an organisation and are usually beyond the control of management. This framework has been empirically tested by many studies and has been found useful in understanding the adoption of technological innovations (Tornatzky *et al.*, 1990).

In addition to the diffusion of innovation theory (Rogers, 2003) and adoption of information technology innovation theory (Moore *et al.*, 1991), there are other supplementary organisational factors identified by Brown *et al.* (2007) considered to be important in the uptake of an innovation. These are organisational size and readiness. Large organisations typically have more resources than smaller organisations, and are therefore more capable of experimenting with new technology. As a result, large organisations are more likely to adopt a new technology (Premkumar *et al.*, 1999). Organisational readiness is a second factor which influences the uptake of a new technology, given that organisations must be willing and prepared to make changes in order for new technology to be implemented and to function successfully.

4.10 Summary of Constructs

Of the seven theories discussed in the previous section, there are five constructs believed to be significant determinants of user acceptance of a new technology or innovation. These are performance expectancy, effort expectancy, social influence, facilitating conditions and attitude towards using a particular technology (Venkatesh *et al.*, 2003). The five constructs taken from the previous models are summarised in the tables below.

4.10.1 Performance Expectancy

Performance expectancy is defined as the degree to which an individual believes that using the system will help him or her to attain greater job performance (Venkatesh *et al.*, 2003). The four constructs from the different models that pertain to performance expectancy are summarised in Table 5. These constructs are: perceived usefulness, job-fit, relative advantage, and outcome expectations. Even as these constructs evolved in the literature, some authors acknowledged their similarities, such as

usefulness and job-fit (Thompson *et al.,* 1991), usefulness and relative advantage (Davis *et al.,*, 1989; Moore *et al.*, 1991; Plouffe, Hulland and Vandenbosch, 2001), usefulness and outcome expectations (Compeau and Higgins, 1995; Davis *et al.*, 1989), and job-fit and outcome expectations (Compeau and Higgins, 1995).

Performance Expectancy		
Construct	**Definition**	**Scale Items**
Perceived Usefulness (Davis, 1989; Davis *et al.,* 1989)	The degree to which a person believes that using a particular system would enhance his or her job performance.	1. Using the system would enable the employee to accomplish tasks more quickly. 2. Using the system would improve employee's job performance. 3. Using the system would increase the employee's productivity. 4. Using the system would enhance effectiveness on the job. 5. Using the system would make it easier to do job. 6. Employee would find the system useful in the workplace.
Job-fit (Thompson *et al.,* 1991)	How the capabilities of a system enhance an individual's job performance.	1. Using the system will have no effect on the performance of the employee's job. 2. Using the system can decrease the time needed for an important job responsibilities. 3. Using the system can significantly increase the quality of output. 4. Using the system can increase the effectiveness of performing job tasks. 5. Using the system the quantity of output for the same amount of effort. 6. Considering all tasks, the general extent to which use of the system could assist on the job.
Relative Advantage (Rogers, 2003)	The degree to which using an innovation is perceived as being better than using its precursor.	1. Using the system enables employees to accomplish tasks more quickly. 2. Using the system improves the quality of the work.

		3. Using the system makes it easier to do the job. 4. Using the system enhances effectiveness on the job. 5. Using the system increases productivity.
Outcome Expectations (Compeau *et al.,* 1995; Compeau *et al.,* 1999)	Outcome expectations relate to the consequences of the behaviour. Based on empirical evidence, they were separated into performance expectations (job-related) and personal expectations (individual goals).	If employee uses the system… 1. They will increase effectiveness on the job. 2. They will spend less time on routine job tasks. 3. They will increase the quality of their output. 4. They will increase the quantity of output for the same amount of effort. 5. Co-workers will perceive the employee as competent, resulting in career benefits.

Table 5: Performance Expectancy

4.10.2 Effort Expectancy

Effort expectancy is defined as the degree of ease associated with the use of the system (Venkatesh *et al.*, 2003). Two constructs from the existing models capture the concept of effort expectancy: perceived ease of use and complexity. Effort-oriented constructs are expected to be more prominent in the early stages of a new behaviour, when process issues represent hurdles to be overcome, and later become overshadowed by instrumentality concerns (Davis *et al.,* 1989; Szajna, 1996; Venkatesh, 1999).

Effort Expectancy		
Construct	**Definition**	**Scale Items**
Perceived Ease of Use (Davis, 1989; Davis *et al.*, 1989; Moore *et al.*, 1991)	The degree to which a person believes that using a system would be free of effort.	1. Learning to operate the system would be easy for employees. 2. Employee would find it easy to get the system to do what they want it to do. 3. Interaction with the system would be clear and understandable.

		4. Employees would find the system to be flexible to interact with. 5. It would be easy for employees to become skilful at using the system.
Complexity (Rogers, 2003)	The degree to which a system is perceived as relatively difficult to understand and use.	1. Using the system takes too much time from normal duties. 2. Working with the system is so complicated, it is difficult to understand what is going on. 3. Using the system involves too much time doing mechanical operations, such as data input. 4. It takes too long to learn how to use the system to make it worth the effort.

Table 6: Effort Expectancy

4.10.3 Social Influence

Social influence is defined as the degree to which an individual perceives that important others believe he or she should use the new system (Venkatesh *et al.*, 2003). Social influence as a direct determinant of behavioural intention is represented as subjective norm, social factors and image. Thompson *et al.* (1991) used the term social norms in defining their construct, and acknowledge its similarity to subjective norms within TRA. While they have different labels, each of these constructs contains the explicit or implicit notion that the individual's behaviour is influenced by the way in which they believe others will view them as a result of having used the technology.

In mandatory settings, where users are forced to use certain technology, social influence appears to be important only in the early stages of individual experience with technology, with its role eroding over time and eventually becoming insignificant (Agarwal *et al.*, 1997; Hartwick and Barki, 1994; Taylor and Todd, 1995a; Thompson, Higgins and Howell, 1994; Venkatesh and Davis, 2000).

Social Influence		
Construct	**Definition**	**Scale Items**
Subjective Norm (Ajzen, 1991; Davis *et al.,* 1989; Fishbein *et al.*, 1975; Mathieson, 1991; Taylor and Todd, 1995a)	The person's perception that most people who are important to him think he should or should not perform the behaviour in question.	1. People who influence the employee's behaviour think that they should use the system. 2. People who are important to the employee think that they should use the system.
Social Factors (Thompson *et al.,* 1991)	The individual's internalisation of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations.	1. Employee uses the system because of the proportion of co-workers who use the system. 2. The senior management of this business has been helpful in the use of the system. 3. Employee's supervisor is very supportive of the use of the system. 4. In general, the organisation has supported the use of the system.
Image (Moore *et al.*, 1991)	The degree to which use of an innovation is perceived to enhance one's image or status in one's social system.	1. People in the organisation who use the system have more prestige than those who do not. 2. People in the organisation who use the system have a high profile. 3. Having the system is a status symbol in the organisation.

Table 7: Social Influence

4.10.4 Facilitating Conditions

Facilitating conditions are defined as the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system (Venkatesh *et al.*, 2003). This definition captures concepts embodied by three different constructs: perceived behavioural control, facilitating conditions, and compatibility. Each of these constructs is working to include aspects of the technological and organisational environment that are designed to remove barriers to use.

The effect is expected to increase with experience as users of technology find multiple avenues for help and support throughout the organisation, thereby removing impediments to sustained usage (Bergeron, Rivard and De Serre., 1990).

Facilitating Conditions		
Construct	**Definition**	**Scale Items**
Perceived Behavioral Control (Ajzen, 1991; Taylor and Todd, 1995a)	Reflects perceptions of internal and external constraints on behaviour and encompasses self-efficacy, resource facilitating conditions, and technology facilitating conditions.	1. Employee has control over using the system. 2. Employee has the resources necessary to use the system. 3. Employee has the knowledge necessary to use the system. 4. Given the resources, opportunities and knowledge it takes to use the system, it would be easy for employee to use the system. 5. The system is not compatible with other systems in use.
Facilitating Conditions (Thompson *et al.,* 1991)	Objective factors in the environment that observers agree make an act easy to do, including the provision of computer support.	1. Guidance was available to employee in the selection of the system. 2. Specialised instruction concerning the system was available. 3. A specific person (or group) is available for assistance with system difficulties.
Compatibility (Rogers, 2003; Moore *et al.*, 1991)	The degree to which an innovation is perceived as being consistent with existing values, needs, and experiences of potential adopters.	1. Using the system is compatible with all aspects of employee's work. 2. Employee thinks that using the system fits well with the way they like to work. 3. Using the system fits into employee's work style.

Table 8: Facilitating Conditions

4.10.5 Attitude Towards Using Technology

Attitude toward using technology is defined as an individual's overall affective reaction to using a system (Venkatesh *et al.*, 2003). Three constructs from the existing models align closely with this definition: attitude toward behaviour; affect toward use; and affect. Table 9 presents the definitions and associated scale items for each construct. Each construct has a component associated with generalised affect associated with a given behaviour, in this case, using technology. In examining these three constructs, it is evident that they all focus on an individual's liking, enjoyment, joy, and pleasure associated with technology use.

Attitude Towards Using Technology		
Construct	**Definition**	**Scale Items**
Attitude Toward Behaviour (Davis *et al.,* 1989; Fishbein *et al.*, 1975; Taylor and Todd, 1995a)	An individual's positive or negative feelings about performing the target behaviour.	1. Using the system is a bad or good idea. 2. Using the system is a foolish or wise idea. 3. Employee dislikes or likes the idea of using the system. 4. Using the system is unpleasant or pleasant.
Affect Toward Use (Thompson *et al.,* 1991)	Feelings of joy, elation, or pleasure; or depression, disgust, displeasure, or hate associated by an individual with a particular act.	1. The system makes work more interesting. 2. Working with the system is fun. 3. The system is alright for some jobs, but not the kind of job employee want.
Affect (Compeau *et al.,* 1995; Compeau *et al.,* 1999)	An individual's liking of the behaviour.	1. Employee likes working with the system. 2. Employee looks forward to those aspects of the job that require the use of the system. 3. Using the system is frustrating. 4. Once employee starts working on the system, they find it hard to stop. 5. Employees get bored quickly when using the system.

Table 9: Attitude Towards Using Technology

4.11 Conclusion

Many factors can influence the likelihood of an innovation being adopted. Analysis of these factors suggests that diffusion of innovation plays an important role in determining the acceptance of an innovation and patterns of growth.

The diffusion of innovation study proposes several theories, and these theories can be grouped under individual-level and organisational-level technology adoption, each theory addressing particular adoption constraints with a view to understanding how individuals, organisations as well as groups may perceive the viability of adopting a particular innovation. Put together, individual-level technology adoption (TRA, TAM, TPB, MPCU, extended SCT) and organisational-level technology adoption (adoption of IT innovation theory and the diffusion of innovation model), represent a wealth of knowledge regarding the innovation adoption process. These theories provide evidence that a variety of factors influence whether potential adopters and consumers will accept or reject new technology within a social system (Baskerville and Pries-Heje, 2001).

Chapter 5

Adoption Barriers to RFID Technology in the Retail Sector

The previous chapter explored the diffusion of innovation as it influences the adoption of an innovation, such as RFID. This chapter presents several models believed to be pertinent to understanding the barriers to RFID adoption within the retail sector. The diffusion of innovation constructs in Chapter 4 together with the adoption barriers in Chapter 5 are combined to inform the proposed framework for Chapter 6.

5.1 Introduction

There are numerous benefits that retailers can derive from RFID. As suggested in previous chapters, these include efficient storage and management functionality; tagged goods may be tracked throughout the supply chain simplifying inventory management (Jones, Clarke-Hill, Shears, Comfort and Hillier, 2004).

There are however a number of challenges currently hindering the widespread adoption of RFID in the marketplace. These challenges can pose significant risks to retail supply chains as they consider implementing RFID (Eckfeldt, 2005). In order to develop successful migration strategies, economic, technical and implementation issues need to be considered. Furthermore, retailers must be mindful of security and privacy issues surrounding the technology (Curtin, Kauffman and Riggins, 2007; Shepard, 2004:124).

5.2 Findings of barriers to RFID adoption

The following section provides insight into research conducted by several individuals as well as organisations on the barriers to RFID adoption. Barriers mentioned for the first time are explored in detail whereas barriers reintroduced by subsequent authors are simply noted.

5.2.1 Montgomery's Barriers to the adoption of RFID

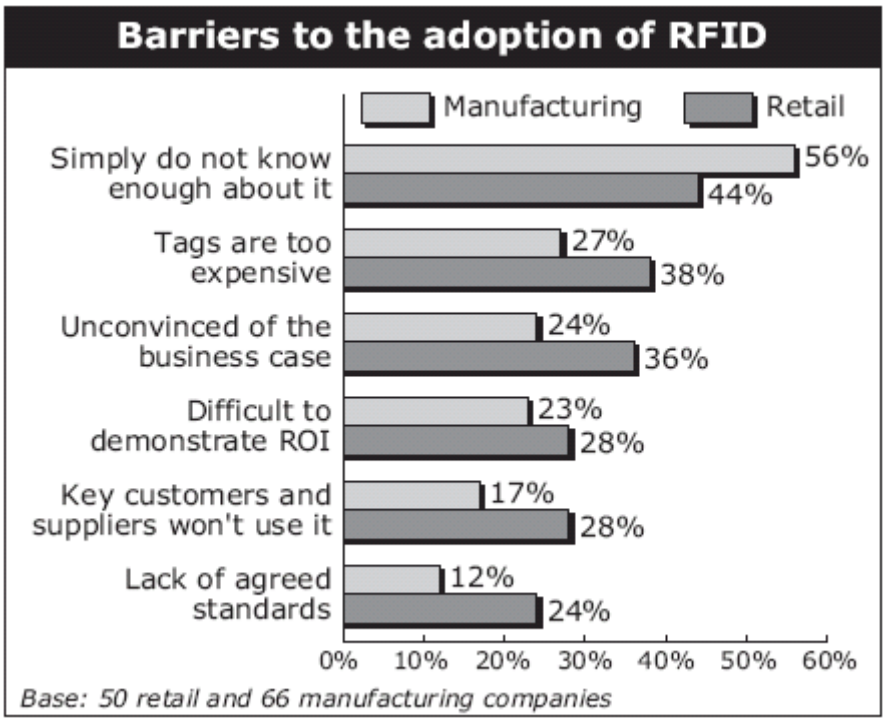

Figure 17: Barriers to the adoption of RFID (Montgomery, 2006)

5.2.1.1 Lack of Awareness

According to Montgomery (2006), the most obvious barrier to the adoption of RFID technology lies in a lack of awareness and education, which constitutes 44 percent of the retail sector. Furthermore, half the potential retail market of large businesses consist of senior decision makers who currently have no real idea what RFID is or how it can benefit their organisation. As shown in Figure 18, 60 percent of the respondents either have not heard about RFID technology or know little about it, 26 percent of respondents are vaguely familiar with it, and only 14 percent of respondents are either reasonably or very familiar with the technology (Montgomery, 2006). Due to a lack of knowledge and education in RFID technology, most organisations have not realised the great benefits that RFID brings, and as a result, the majority of respondents have taken a wait-and-see stance towards RFID adoption.

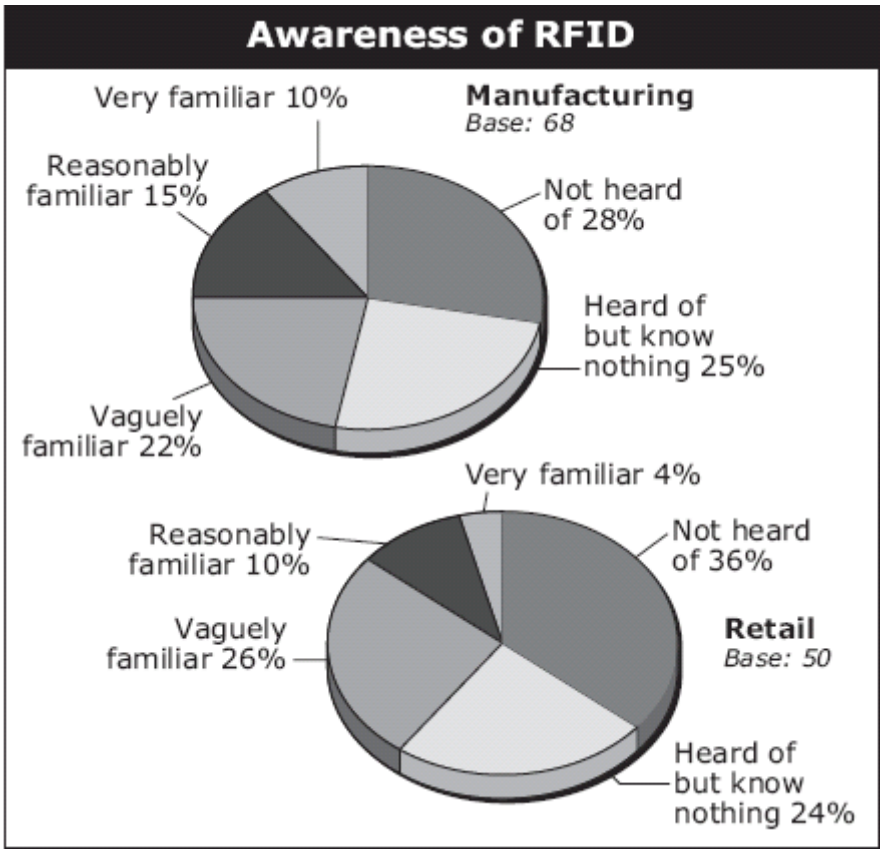

Figure 18: Awareness of RFID (Montgomery, 2006)

5.2.1.2 High cost concerns

In addition, there is a widely held view within the retail sector that tags are too expensive. It is clear that economic viability would depend on the value of the products or items involved (Montgomery, 2006). The higher priced tags can be easily justified when attached to higher value items, but become unfeasible when used on items of lower value.

Shister (2005) agrees with Montgomery (2006) that one of the biggest challenges facing the RFID industry has been tag costs. It is believed that while costs remain high, the demand for RFID technology will be negatively impacted (Davison and Smith, 2005). Although the prices of tags are falling, they still represent a significant cost, which makes them impractical for identifying millions of low-cost items (Shister, 2005; Swedberg, 2006). RFID Technologies CC (2007), a South African manufacturer and distributor of RFID equipment, charges R7.20 for each passive tag with orders of a million or more, and for low volume orders, it is even more expensive. Sullivan (2005) and Montgomery (2006) agree that applying tags to thousands of

items is an expensive task, particularly low-cost items where the item is worth much the same as the tag. Therefore, the cost of an individual tag becomes crucial at the item level. Though tags are still priced higher than the industry's expectation (Shister, 2005), the prices will drop as the technology usage grows. It is not only the high cost of tags that negatively impact RFID adoption, but as Shister (2005) suggests, it is also the high cost of equipment that is holding back RFID adoption. At current 2007 market prices, readers cost approximately R10 000 on average, yet some may cost even more (RFID Technologies CC, 2007; Trolley Scan, 2006). Companies would need many readers to cover all their factories, warehouses and stores. Furthermore, integration between different systems is a difficult and complex task, and software plays an important role in the success of system integration. The software which connects a RFID system to a retail system sometimes has an even higher cost than the hardware, and prices can vary significantly between different vendors. For instance, Trolley Scan (2007), another South African RFID trading company, is offering an RFID starter programme that costs between R1 600 and R3 200. This programme provides simple detect and display functions that only allow organisations to identify RFID tags and display information stored on the tag. In addition, RFID readers collect large amounts of data, most of which is redundant or irrelevant. Middleware, which is software designed to integrate separate software and hardware systems, is then used to filter out redundant or irrelevant data and collect necessary data in a usable form to track products, trace the history of items, trigger shipping and receive materials. According to Evolving Management Solutions (2007), middleware can cost as much as R12 000. By comparison, conventional barcode labels cost less than a cent on average and a barcode reader can cost less than R1 500. Furthermore, barcodes do not need any special infrastructure, unlike RFID technology. Seymour, Lambert-Porter and Willuweit (2007) and Wu, Nystrom, Lin and Yu (2006) also suggested that one of the challenges in RFID adoption is the significant cost associated with hardware, software and tags, hence, these costs mitigate RFID adoption.

Although an RFID system might decrease labour costs, the investment in implementing this technology might be much higher than the cost saving in labour (Lee *et al.*, 2005). As a result, most organisations are holding back the adoption of RFID technology at the time of writing (Shister, 2005).

5.2.1.3 Lack of business case or unconvinced business case

The third major barrier for RFID adoption revealed by Montgomery (2006) is the unconvincing business case, which was cited by 24 percent of respondents from the retail sector. The business case is a report that highlights economic benefits, costs, and the technical and organisational feasibility of the proposed project. Every aspect has a major influence on the decision to adopt RFID or not, and any uncertainty will result in retailers holding back. Malykhina (2006) and Davison and Smith (2005) concur with Montgomery (2006), and suggest that uncertainty in the business case that outlines the justification for the adoption of RFID means that higher risk will cause hesitation in the retailer's uptake of RFID.

5.2.1.4 Unclear ROI

Furthermore, Montgomery (2006) suggests that it is hard to obtain information on costs and benefits; therefore, it is difficult to demonstrate return on investment (ROI) for RFID adoption. In fact, concerns surrounding ROI constitute 23 percent of the total response from the retail sector. According to Sandip (2005), ROI is an important consideration in assessing RFID investments. Expectations of RFID benefits can be broken down into two parts: the first part refers to cost reduction, such as labour cost reduction, inventory cost reduction, process automation, and efficiency improvements. The second part is value creation such as revenue increases, increases in customer satisfaction due to responsiveness, and anti-counterfeiting. It is difficult to calculate the true returns based on limited benefit information from pilot projects in segmented RFID system installations. Subsequently, ROI for RFID solutions might be unclear (Karkkainen, 2003; Wu *et al.*, 2006), and payback may be extremely lengthy (i.e. more than five years) (Lapide, 2004). It is also noted that RFID benefits and costs might not be shared equally among supply chain members (Blanchard, 2004) and that benefits will differ by industry favouring those with higher product values (Kearney, 2003).

5.2.1.5 Customers and suppliers won't use it

A further concern highlighted in Montgomery's (2006) research revealed that 17 percent of respondents in the retail sector are concerned that key suppliers and customers might not be prepared to embrace RFID technology. According to Montgomery (2006), some retailers indicated they had experienced considerable

resistance from suppliers to adopt bar coding, not to mention RFID. Furthermore, Seymour *et al.* (2007) believed that the end goal of RFID adoption should be satisfy the needs of customers and suppliers, and without such satisfaction, customers and suppliers are reluctant to use RFID technology.

5.2.1.6 Lack of standards

A final and significant RFID adoption challenge relates to standards. According to IDTechEx (2004), Seymour *et al.* (2007) and Wu *et al.* (2006), one of the major factors restricting the development of RFID technology is the disunity of RFID standards. Montgomery (2006) said that if RFID is to be effectively deployed across supply chains that include the retail sector, there will need to be common standards to enable all customers and suppliers to use the technology. Both Roberts (2006) and Twist (2005) argue that a global standard is needed to ensure interoperability and cost reduction. They suggest there are two major problems with RFID standards. Firstly, there is the lack of a unified RFID standard. As discussed in Chapter 3. Several groups are now actively developing technical RFID standards, two of these being EPCglobal and International Standards Organization (ISO) (Sandip, 2005; Wu *et al.*, 2006). Both organisations are still evolving and are not fully compatible with each other. A lack of standards might be causing retailers to hold off until there is a unified standard they can follow to avoid the risk of embracing the wrong one. Clearly, retailers do not want to invest in an RFID standard that could become worthless in the future (Jakovljevic, 2004).

Secondly, there is a lack of consistent UHF spectrum allocated for RFID. Regulations on radio spectrum allocated for RFID use are not unified internationally. A large portion of the UHF spectrum has already been auctioned to cellular phone service providers for high licence fees by a few countries. It would be difficult to buy that portion of spectrum back for RFID use. To add complexity to the adoption of RFID, the tags that respond only to a specific UHF frequency range cannot be read in countries where different spectrum bands are allocated for RFID use (Roberts, 2006; Twist, 2005).

5.2.2 The Aberdeen Group's Obstacles to RFID Adoption

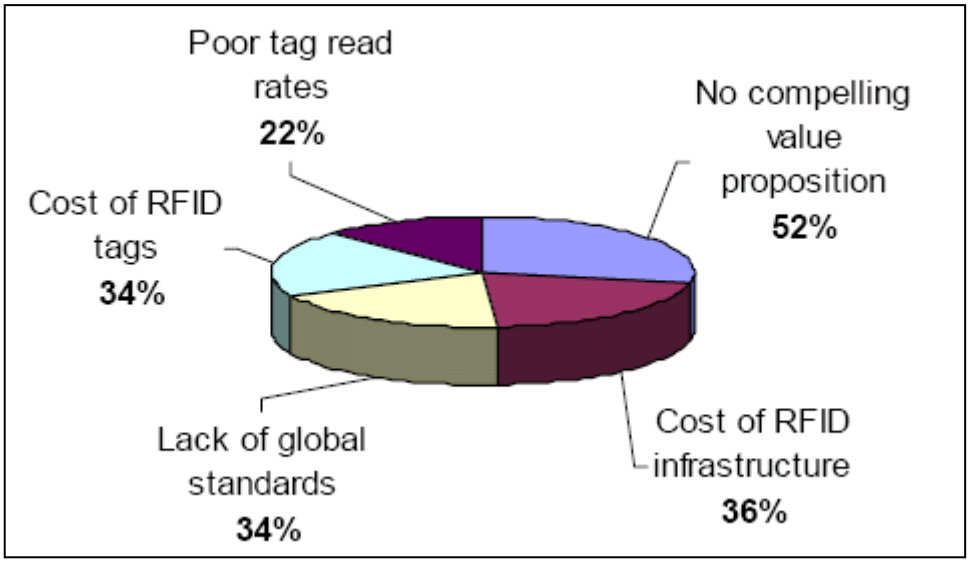

Figure 19: Obstacles to RFID Adoption (Aberdeen Group, 2005)

5.2.2.1 No compelling value proposition

Additional research on the obstacles to RFID adoption conducted by the Aberdeen Group (2005) revealed that 52 percent of respondents believe there is no compelling value proposition in RFID adoption. In the context of the retail sector, this means that RFID adoption has no convincing value relative to their alternative choice, which is the barcode system. Seymour *et al.* (2007) suggest that perceived value in RFID technology is a core component in technology adoption. Diffusion of innovation theory identified that relative advantage (Rogers, 2003) and perceived usefulness (Davis, 1989) are key factors to consider for the acceptance of an innovation. This coincides with the Aberdeen Group's (2005) view on lack of compelling value proposition, because retailers are reluctant to implement RFID if there is no additional value perceived by the general public or potential adopters.

5.2.2.2 High cost of hardware and infrastructure

Like Montgomery (2006), the Aberdeen Group (2005) recognises that the cost of tags is too high, and it is therefore not viable to tag every product, particularly where the cost of a product is lower than the cost of a tag. The Aberdeen Group (2005) also found that 36 percent of the respondents consider the high cost of RFID infrastructure another major obstacle for RFID adoption. RFID infrastructure refers to RFID readers or writers, associated computers, servers, software and other physical

equipment such as cabling. Both the Aberdeen Group (2005) and Montgomery (2006) identified the lack of global standards as a key challenge for RFID adoption. This was discussed in detail in the previous section.

5.2.2.3 Poor tag read rates

Finally, the Aberdeen Group (2005) discovered that poor tag read rates influence the performance of RFID technology, negatively impacting the uptake of RFID technology. MPCU identified that job-fit (Thompson *et al.,* 1991) is an important factor when using an innovation, given that it must improve the efficiency and effectiveness of individual's performance and business process; therefore, poor tag read rates will hinder the acceptance of RFID technology, resulting in lower adoption rates. According to O'Brien and Swartz (2004), environmental and human factors can negatively affect the performance of RFID systems. One of the primary issues is the current reliability of the technology itself. In particular, many users have found tag readability to be significantly less than 100 percent due to a variety of factors including inconsistency across different reader brands, chip and antenna defect rates, signal distortion/reflection/absorption, and signal collision with multiple tags and readers (Angeles, 2005; Asif and Mandviwalla, 2005; Jones *et al.*, 2004; Richardson, 2004; Seymour *et al.*, 2007; Wu *et al.*, 2006). For example, RF signals are subject to interference from environmental factors commonly found in manufacturing, warehousing, and retail settings, including static electricity, wireless access points, wireless mice/keyboards, radios, fluorescent lights, metal-to-metal banging, and electrical motors. The presence of dense liquids and metals in products and packaging can also interfere with RFID signals. Poor or incorrect use of reader equipment or collision problems caused by too many simultaneous reads can hamper RFID performance and impact the quality of data collected. However, the risk of bad data is decreasing significantly as technology improves (Angeles, 2005; Asif *et al.*, 2005).

It is important to be aware of these factors in relation to the specific business applications, including the nature of premises, the training and competencies of staff and the composition, and the scale or amount of goods to be tagged improves (Asif *et al.*, 2005).

5.2.3 Swanton's Most Important Obstacles to RFID Adoption

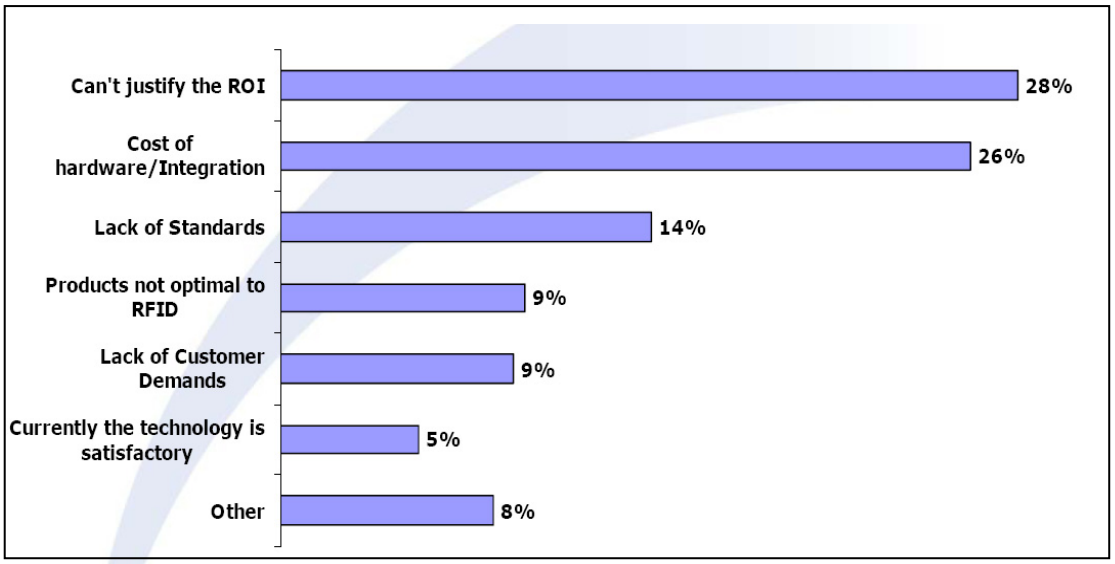

Figure 20: Most important challenge/obstacle with regard to RFID Technology adoption (Swanton, 2005)

5.2.3.1 High cost of integration

Swanton (2005) identified the major challenges in RFID adoption as: justifying the ROI; and the high costs of hardware. While this view corresponds with research conducted by Montgomery (2006) and the Aberdeen Group (2005), Swanton (2005) and Weinstein (2005), by contrast, highlight concerns regarding the costs associated with integration. Weinstein (2005) regards system integration as a key consideration in RFID adoption. It is also very important that data generated from an RFID system are in a format that is compatible with all of the relevant equipment, software and other data (Angeles, 2005). The more an RFID system is interoperable with both legacy systems and with the systems of suppliers and customers, the greater the potential value to be derived from it. Third party data formats, communication protocols, hardware platforms and software systems need to be carefully considered for compatibility issues and the potential for effective integration when installing an RFID system (Angeles, 2005).

Roger (2003) suggested that trialability of an innovation provides an in-depth understanding and also clears any uncertainties. Therefore, in order to ensure that RFID systems will be interoperable with the systems currently utilised in business, companies need to consult with vendors, suppliers and customers and perhaps also run trials to confirm interoperability. This then requires companies to invest significantly

in consultation and trial. Swanton (2005) believes that the cost for integration with current internal business systems will vary based on many factors, such as software upgrades, internal resource costs, and optional costs associated with custom development or system configuration changes. Integrating RFID middleware could be one of the costlier aspects of RFID deployment, especially for larger consumer goods and retail companies. These two aspects combined constitute over 50 percent of the barriers perceived by all the respondents (Swanton, 2005).

Swanton (2005) also revealed that the lack of standards of RFID systems and the satisfaction with current barcode technology are two barriers holding back the adoption of RFID. As mentioned previously, lack of RFID standards will result in incompatibility with other vendors using RFID systems, which will naturally result in a breakdown in the supply chain with tags that cannot be read upstream or downstream (refer to 5.2.1.6 Lack of standards). As RFID develops, however, standards are gradually converging.

5.2.3.2 Current technology in place is satisfactory

While the previous section has highlighted various barriers, it is important to note that some respondents as revealed in Finkenzeller's (2003) research are simply happy with current barcode identification technology and do not see the additional value in changing to RFID technology. This view corresponds with the Aberdeen Group (2005), who suggests there is no compelling value proposition with RFID technology.

Finkenzeller (2003) argues that over the past two decades, barcodes have been used widely from factory floors to neighbourhood supermarkets. They are universally accepted for having improved data input productivity as well as data quality over manual keyboarding. In particular, the pervasiveness of barcode technology may be the greatest barrier to RFID in the retail sector. What's more, barcode technology is still developing with the introduction of the 3D bar coding system. The so-called Bumpy Barcode (BBC) was developed by Mecco Marking & Traceability and comprises a linear barcode (such as a 1D or 2D barcode) embossed on a surface such that the code has a third (height) dimension. Therefore, the 3D barcode can be read by using differences in height, rather than contrast, to distinguish between bars and spaces using a special reader (Jones and Kenen, 2005). Examples of 3D barcode

usage are where typical 1D and 2D barcodes cannot be easily placed (such as where printed labels will not adhere) or situations where ID or 2D barcodes can be destroyed by a hostile or abrasive environment. As a result, the application of barcode systems is actually expanding without the need to replace current infrastructure. Some respondents expressed concern that migration from barcode to RFID systems will not only increase the demand on system capabilities and compatibilities but also increase costs on maintenance and operation of both systems, which is an additional reason not to deploy an RFID system.

5.2.3.3 Lack of customer demands and products not optimal to RFID

Swanton (2005) identified two additional obstacles to RFID adoption. These are products not being suited to RFID tagging and a lack of customer demand. Nine percent of respondents believe that some products are not suitable for use with RFID technology. For example, products that contain metal and liquids interfere with the RF signal. Also nine percent of the respondents believe that lack of customer demand is an influential factor, since customers who are happy with currently identification technology will not feel the urgency to use new technology and therefore will not provide the pressure on companies to deploy an alternate technology, such as RFID. Seymour *et al.* (2007) agree with Swanton (2005), and suggest that without the needs of RFID technology from the customer, there will be no demand for RFID adoption in the retail sector.

5.2.4 Venture Development Corporation's explanation for CPG organisations not using RFID technology

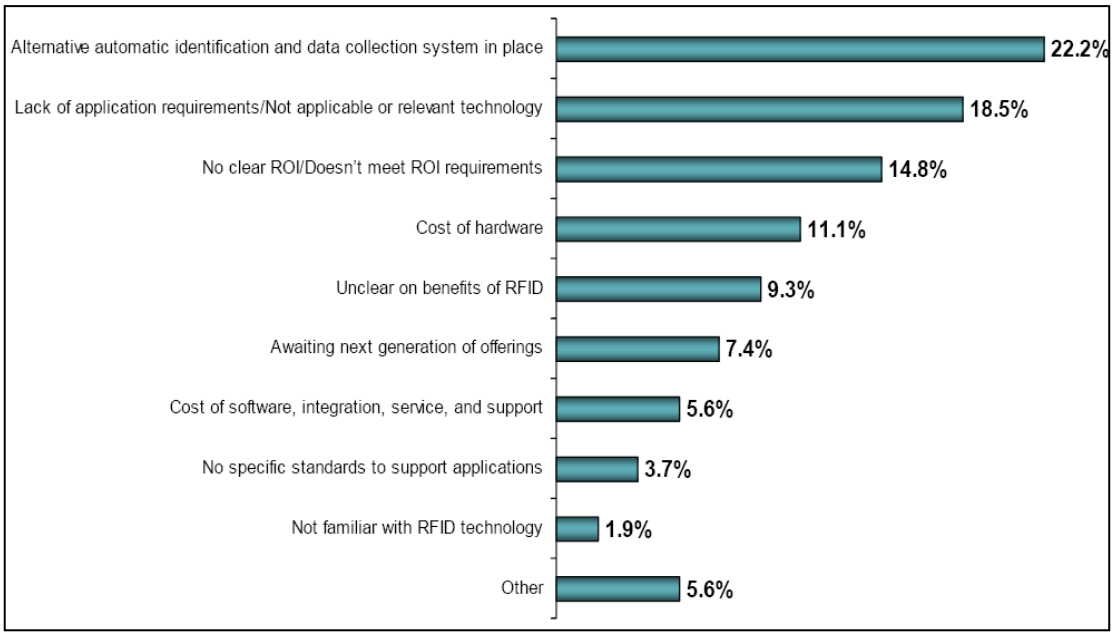

Figure 21: Primary reasons for not using or evaluating RFID based on CPG organisations (Venture Development Corporation, 2006).

Research conducted by the Venture Development Corporation (VDC) (2006), an independent technology market research and strategy consulting firm, revealed similar adoption constraints to those previously discussed by Swanton (2005), Aberdeen Group (2005), and Montgomery (2006).

These common barriers include:

- Alternative automatic identification and data collection system in place
  The existence of an automatic identification and data collection system such as barcode technology gets the job done, without the need for RFID technology. This view corresponds with that of Swanton (2005).
- No clear Return on Investment (ROI) or does not meet ROI requirements
  As noted by both Venture Development Corporation (2006) and Montgomery (2006), there is no clear ROI report that can identify this obvious benefits of RFID deployment; therefore, most respondents are still waiting and observing the early adopters on their deployment and ROI analysis.

- Cost of hardware

  Again, both Venture Development Corporation (2006) and Swanton (2005) argued that the cost of RFID hardware is relatively high.
- No specific standards to support application

  This view corresponds with that of all three authors previously discussed (refer to 5.2.1.6 Lack of standards).
- Not familiar with RFID technology

  Most retail companies are not aware of the technology and therefore, are not informed of its relative benefits (refer to 5.2.1.1 Lack of awareness).

Unique constraints highlighted by Venture Development Corporation (2006) are described in detail below:

5.2.4.1 Lack of application requirements/not applicable or relevant technology

VDC noted that RFID technology has no proper application requirements that retailers can make use of when deploying RFID or the technology is not appropriate for the application, hence, respondents are not considering RFID. In addition, Seymour *et al.* (2007) and Davis (1989) found that the perceived usefulness of RFID is a consideration factor for most organisations considering this technology.

5.2.4.2 Unclear benefits of RFID

Research found that some respondents are not clear about the benefits of RFID technology when deployed. According to Rogers (2003) and Seymour *et al.* (2007), relative advantage is one of the crucial factors in technology adoption, and insufficient advantage will cause retailers to hold back RFID adoption.

5.2.4.3 Awaiting next generation of offerings

According to the research, some respondents are waiting for the next generation of RFID technology, hoping that most of the current technical issues will be solved, costs reduced and standards unified.

5.2.4.4 High cost of software, integration, service, and support

The Venture Development Corporation (2006) agrees with Swanton (2005) that the cost of software and integration, in relative terms, are too high. In addition, VDC also identified the cost of RFID service and support as being a major issue. Hiring a third-party consultant such as IBM for its service and support is costly, but necessary, as most companies would be new to RFID technology, and would therefore require a consultant to assist with the deployment. These additional costs of service and support must be taken into consideration.

5.2.5 A.T. Kearney and Kurt Salmon Associates' major barriers expected to RFID adoption

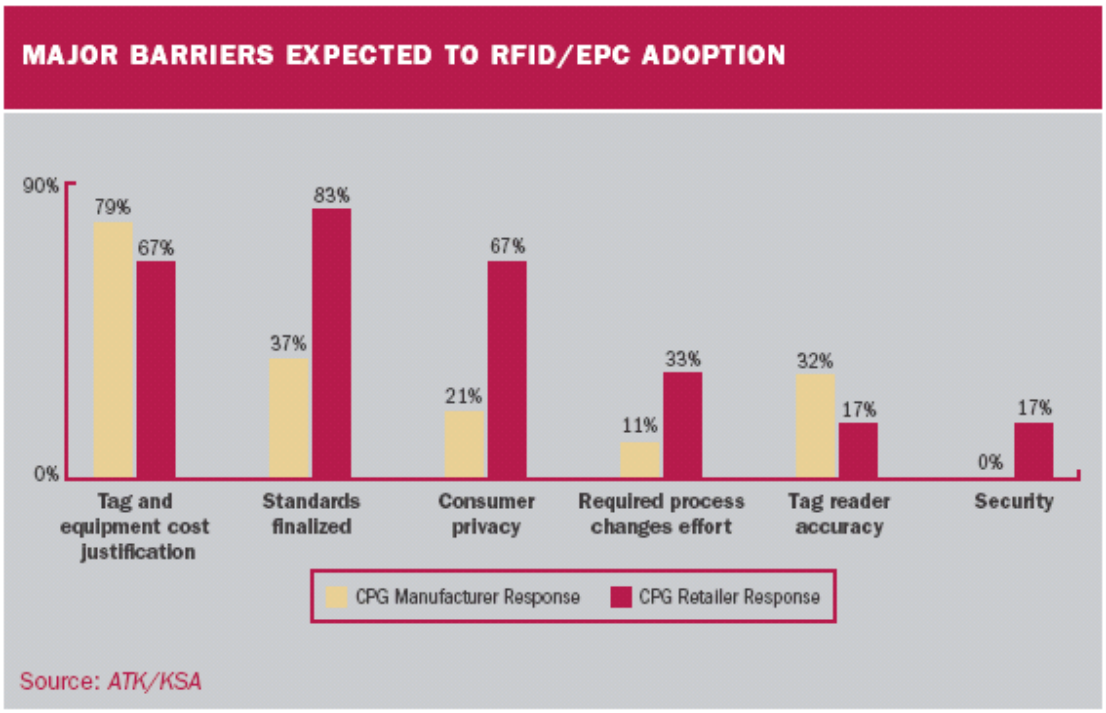

Figure 22: Major barriers expected to RFID/EPC Adoption (ATK and KSA, 2004).

A.T. Kearney (ATK) is a corporate-focused management consulting firm and Kurt Salmon Associates (KSA) is also a management consulting firm specialising in retailing, consumer products, and health care. The two firms conducted joint research on the major barriers to RFID adoption. Again, their research outcomes provide insight into what retailers perceive to be the barriers to RFID adoption. According to their research, most retailers considered RFID tag and equipment costs to be a major issue, as were concerns about global standards. Referring to Figure 22, their findings

correspond with all the above-mentioned authors or firms, both in the retail sector and other sectors.

5.2.5.1 Poor tag reader accuracy

ATK and KSA (2004) together with the Aberdeen Group (2005), cited tag reader accuracy concerns among retailers. Given the example of a retail point of sale where a customer is attempting to checkout a trolley of tagged goods, unless the retailer can be sure of the RFID readers' accuracy, the retailer could face major problems as tagged items remain undetected or a single item might be recorded several times, effectively resulting in under or overcharging respectively.

5.2.5.2 Consumer privacy concerns

So far, most retailers seem to use RFID only in inventory monitoring, security, and anti-counterfeiting areas because of customer privacy threats (Bhuptani and Moradpour, 2005:158; Roberts, 2006; Luckett, 2004). In fact, ATK and KSA (2004) suggest that retailers are more sensitive to consumer privacy issues than manufacturers are. Since retailers are involved directly with consumers, and consumers are concerned about the confidentiality of their personal information, the retailer sector is more concerned about consumer privacy than any other sector.

To illustrate this, Benetton, a global upmarket clothing manufacturer and retailer, was forced to withdraw plans to use RFID tags in their retail outlets when privacy protection groups and advocates protested about privacy. The company eventually resolved to use RFID tags up to the garment evaluation stage (Blanchard, 2003). In November 2003, a group of consumer privacy and civil liberties groups issued a three-point position statement arguing for a wide variety of regulatory restrictions on RFID.

- Firstly, the groups called for RFID systems in the consumer goods context to be indefinitely delayed while a technology assessment is undertaken
- Secondly, the group insisted that regulations need to put in place for RFID systems. They proposed the so-called "strong principles of fair information practices" which include information policies put forward by international bureaucrats that address safeguarding privacy.

- Finally, they called for an outright ban on certain potential practices, such as using RFID in a way to eliminate or reduce anonymity, even though a common use of RFID technology today is in identification tags.

Thus, the biggest issues surrounding public policy associated with the growing use of RFID technology, is privacy (Claburn and Hulme, 2004; Twist, 2005). There is concern in some quarters that the monitoring capabilities of RFID tags will be used to invade the privacy of individuals (Sarma, Weis and Engels, 2002). There are two major aspects surrounding this issue.

Firstly, there is the possibility of leaking information pertaining to personal property. If a generic RFID system is used, anyone can, without restriction, read the connection between the product and the tag and obtain information regarding the tagged contents, such as a tagged item worn on the body, while the owner is unaware of this (Sullivan, 2005).

Secondly, there is the possibility of tracking the consumer's spending history and patterns as well as physical location (Peslak, 2005). If a product ID is specific to an individual; let's say tags are used in clothes and other personal belongings like shoes, watches, and handbags, tracking the person's movements over an extended period becomes possible. Not only can physical location be tracked, but an individual's personal information might also be accessible based on a unique ID. This concern might be especially significant if tracking information can be associated with identity and credit card details, or other personal information.

It is often suggested that RFID technology is 'unregulated', meaning that there are no restrictions on the use of RFID to invade the privacy of individuals or misuse personal information. While there is no specific privacy regulation pertaining to RFID systems by the South African government, there is the general privacy legislation of data contained in the Promotion of Access to Information Act No. 2 (2000) applying to all forms including data gathered through the commercial use of RFID. For example, the Act No. 2 of 2000: Promotion of Access to Information Act in South Africa (Act No. 2 of 2000, 2000), places restrictions on business in relation to how data is collected, handled, stored, used and disclosed.

Legal practitioners from around the world have recommended that basic principles of privacy law be adopted when designing, implementing and using RFID technology (Garfinkel, Juels and Pappu, 2005). They suggest that:

- RFID tags should only be linked to personal information or used to profile customers if there is no other way of achieving this goal.
- Individuals should be fully informed if personal information is collected using RFID tags.
- Personal information collected using RFID tags should be used only for the specific purpose for which it is first collected, and destroyed after that purpose is achieved.
- Individuals should be able to disable or destroy any RFID tag that they have in their possession.

The prospect of widespread item-level tagging in the retail sector appears to be a source of concern from the point of view of customers being unaware that items they are carrying around could be subject to tracking (Sullivan, 2005). According to Molnar and Wagner (2004), large scale item-level tagging in the retail sector is still some years away, but given that three years have passed, some major retailers around the world have started either piloting or using RFID technology in their business, such as Wal-Mart, Metro Group and Mark & Spencer, to name a few. As a result, businesses looking to adopt RFID technology need to be aware that these issues and concerns exist and need to be addressed.

5.2.5.3 High degree of business process change required

ATK and KSA's (2004) research findings also revealed that RFID adoption requires extensive change in business processes. At the core of every business is a set of unique processes, integrated and connected chains of activities that ultimately accomplish what a business sets out to do. These business processes rely on technology to become as efficient as possible. If the business is not prepared to change or optimise its business process based on RFID specifications, then the return on investment will be below an optimal level relative to the vast benefits that can be enabled by RFID. ATK and KSA (2004) suggest that some companies are not willing

to adopt RFID technology because of the high degree of process change, which not only involves enormous effort, but also results in high costs and time delay.

Potential achievements made possible by RFID can be substantial, but, as with other technological advances, they require effective process change. Many organisations have stated that RFID is not a solution or a goal, but is an enabling tool to replace current business processes with ones that are more immediate, more precise and less redundant. This involves great effort in changing current business process, of which most retailers are afraid.

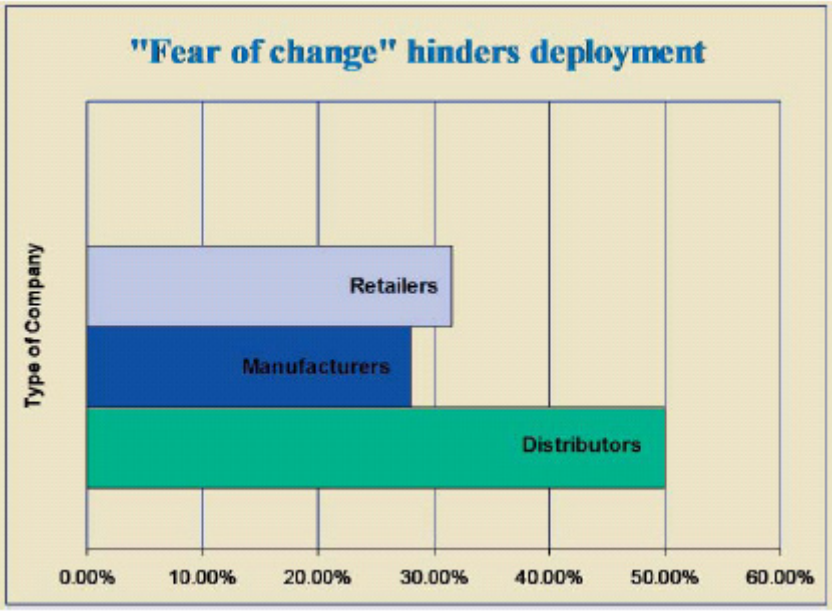

Figure 23: "Fear of change" hinders deployment (Abbott, 2004)

Two of the major factors causing fear of change are organisational structure and culture, which could hinder smooth conversion to RFID in an organisation (Seymour *et al.*, 2007). In a survey conducted by Abbott (2004), a fear of change in the work environment was reported by almost 30 percent of respondents in the retail industry. Another 15 percent indicated that they feel animosity and distrust toward the IT department. Another cultural problem that appears in 20% to 40% of all respondent categories is lack of an innovation culture (Abbott, 2004). As a result, fear of change hinders the adoption of RFID technology. TRA also suggested that attitude towards behaviour is a factor influencing technological acceptance, since reluctance to change from the business or individual would have a direct impact on the adoption of RFID technology. (Davis *et al.*, 1989; Fishbein *et al.*, 1975; Taylor and Todd, 1995a).

5.2.5.4 Security

The last issue identified by ATK and KSA is security. RFID security issues can put credit card consumers and companies at risk from intruders. Like any computer system, an RFID system must be secured against unauthorised access, theft or damage (Seymour *et al.*, 2007; Shepard, 2004:124; Smith, 2005). Therefore, RFID systems should be protected from RFID malware, worms and viruses that can cause serious damage to consumers and companies by stealing personal details and hacking into a company's database.

Retailers might not wish to share product information and other types of data stored on their RFID tags with competitors. RFID systems could also be subject to malicious and accidental damage, either through a physical attack, or via vulnerabilities in the associated computer systems, networks and system software (Sarma *et al.*, 2002). According to Sarma *et al.* (2002), the data generated and used in RFID systems is an asset that should be characterised by:

- Confidentiality: information should only be available to those who have the rights to access it.
- Integrity: information should be modified only by those who are authorised to do so.
- Availability: information should be accessible to those who need it, when they need it and how they need it.

Information generated by an RFID system and shared across a network can, however, be protected using authentication and encryption technologies, as is the case in any other computer system (Juels, 2006).

5.2.6 Davison's barriers to implementing RFID

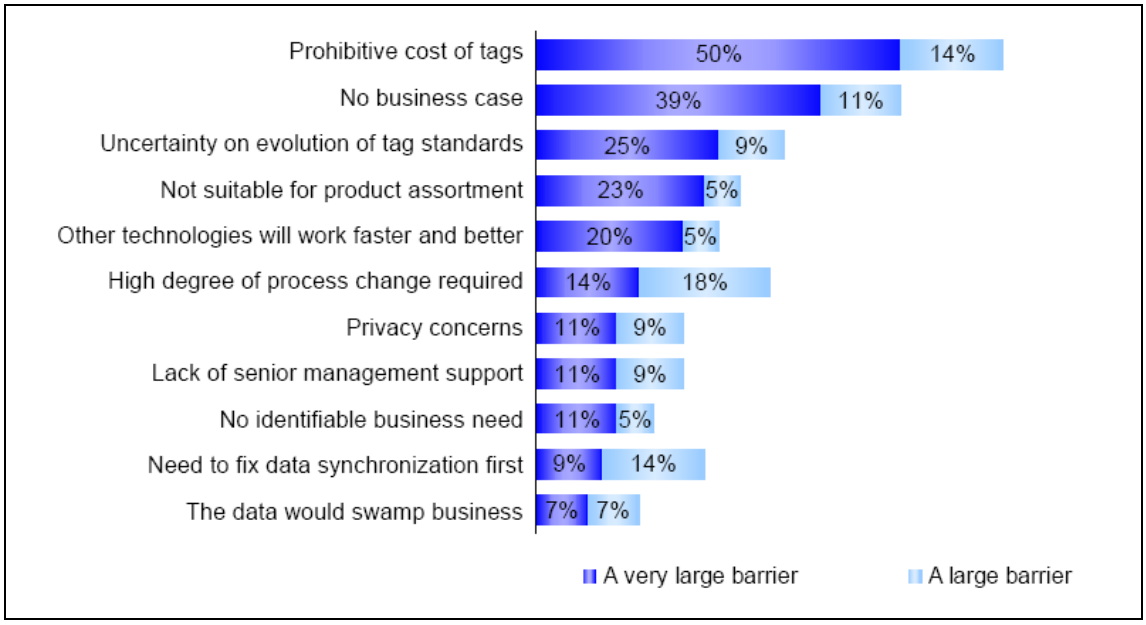

Figure 24: Retailers' views on the barriers to implementing RFID (Davison and Smith, 2005)

Davison and Smith (2005) have identified 11 barriers to RFID adoption based on retailers in the U.S., Canada, U.K., Germany and France, as shown in Figure 24. The majority of the barriers identified by Davison and Smith (2005) have been described in detail in the previous section by Montgomery (2006), the Aberdeen Group (2005), Swanton (2005), VDC (2006), and ATK and KSA (2004).

These common barriers include:

- Prohibitive cost of tags.
- No business case defined for RFID adoption. It is likely that most companies will have to perform a full-scale business case in order to understand the return on investment and then plan for RFID implementation.
- Uncertainty about the evolution of tag standards.
- Other technologies will work faster and better. Twenty percent of the poll respondents believe that there are other technologies, such as barcode technology, which will work faster and better than RFID technology. This view corresponds with Swanton's (2005) and VDC (2006)'s view that the current technology in place is satisfactory.
- High degree of process change required.
- Privacy concerns.

Unique barriers identified by Davison and Smith (2005) are described in detail below:

5.2.6.1 Not suitable for product assortment

Davison and Smith (2005) argued that RFID technology is not suitable for product assortment, which involves classification of products and frequency of purchased goods by customers. Their reason is that RFID readers are used to read items in high volume, rather than individually like a barcode. Therefore, it is complicated for a RFID system to identify individual items at a time for product assortment.

5.2.6.2 Lack of senior management support

Many companies understand that without senior management support, the implementation of a new technology such as RFID is a risky proposition (Davison *et al.*, 2005; Seymour *et al.*, 2007). In most case, RFID adoption would not be approved and therefore impossible to carry out. TRA and extended SCT, as discussed in Chapter 4, identified that attitude towards behaviour and affect are two factors influencing the acceptance of RFID (Davis *et al.*, 1989; Fishbein *et al.*, 1975; Taylor and Todd, 1995a; Compeau *et al.*, 1995 and 1999), given that senior manager's negative feelings about RFID adoption would result in holding back on the mandate.

5.2.6.3 No identifiable business need

Eleven percent of respondents feel that there is no need for RFID technology in their business, because it provides no additional value to the business.

5.2.6.4 The need to fix data synchronisation first

According to Davison and Smith (2005), when suppliers and retailers attempt to communicate with one another using unsynchronised data, there is confusion. Neither party completely understands what the other is requesting. The inaccuracies cause costly errors in a variety of business systems. Therefore, RFID adoption requires data synchronisation first. By synchronising item and supplier data, each organisation works from identical information, thus, minimising miscommunication. Data synchronisation is vital, since it forms the basis of accurate and timely exchange of item and supplier data across organisations.

5.2.6.5 The data would swamp business

Davison and Smith (2005) suggests that the flood of data generated by RFID systems is a challenge that most organisations have to face and 7 percent of the respondents regard it as one of the barriers to RFID adoption. Depending on the size of an organisation, RFID systems can generate gigabytes of data per day. To make matters worse, data changes quickly, so approaching RFID by trying to handle the data volumes in large batches would not work. The volume and velocity of RFID data place a heavy burden on existing technology infrastructure.

5.2.7 Additional barriers to RFID adoption by other authors

The following section highlights additional barriers to RFID adoption as introduced individually by other authors:

5.2.7.1 Lack of skilled personnel

Forrester Research suggests that optimising processes, analysing data, and training workers would cost companies more than the purchase of RFID technology (Walker, 2004). Significant business process questions relating to RFID technology remain unanswered, which means that the organisations will require personnel who can easily integrate technical and business challenges. Such experienced personnel are very hard to find and train (Cooke, 2005). Seymour *et al.* (2007) highlight the lack of expertise as an influential factor in RFID adoption, given that the necessary personnel are required to firstly implement the project and then run the system.

5.2.7.2 Health challenges

There is a concern among some people about the effect of electromagnetic emissions (EME) on human health (Eckfeldt, 2005; Commonwealth of Australia, 2006). Research has not yet identified any health issues associated with exposure to normal emission levels from devices such as mobile phone handsets, electricity distribution infrastructure, and RFID scanning equipment. Concerns might still arise, however, among employees who are required to work near scanning equipment for long periods. These concerns might require sensitive management, whether they are regarded as legitimate or not. It may be prudent to obtain and share expert occupational health

and safety advice or other authoritative information on EME issues in order to reassure affected personnel (Eckfeldt, 2005; Commonwealth of Australia, 2006).

5.2.7.3 Implementation challenges

Implementing RFID is not as straight forward as implementing an off the shelf solution. Significant physical issues are involved in RFID, such as details of antenna configuration (Leong, NG and Cole, 2006), environmental conditions including electromagnetic interference and issues of radiation absorption and obstruction (Asif *et al.*, 2005), and interaction of product materials with tag materials (Michael and McCathie, 2005). Other operational decisions include deciding on the best location to place the reader, the best locations for placing antennae, and locations within the retail supply chain where data should be captured automatically. Thus, considerable engineering skills are required for RFID implementation. Similarly, no packaged solutions are available for software that will be needed to run the RFID infrastructure. Since every organisation will use a unique process model, it may become necessary to develop low level software to handle data communications from readers to enterprise applications, such as the RFID starter program offered by Trolley Scan (2007). Configuring middleware could involve some programming. Specialised troubleshooting and maintenance skills could also be required to keep RFID hardware, software, electrical and radio systems running (Cooke, 2005).

As a result of these challenges mentioned previously, there are RFID consultants helping organisations to roll out their RFID solutions. These consultants provide RFID consulting and implementation services; moreover, they offer specialised RFID software applications (Angeles, 2005). However, these consultants are generally expensive and therefore only affordable by a minority of organisations.

5.2.7.4 Integration challenges

System integration is a key consideration in RFID adoption (Weinstein, 2005). It is very important that data generated from an RFID system are in a format that is compatible with all of the relevant equipment, software and other data (Angeles, 2005; Wu *et al.*, 2006). The more interoperable an RFID system is, both with legacy systems and with the systems of suppliers and customers, the greater the potential value can be derived from it.

Huber, Michael and McCathie (2007) believed that one of the dominant barriers to RFID adoption is integration. Third party data formats, communication protocols, hardware platforms and software systems need to be carefully considered for integration issues and the potential for effective integration when installing an RFID system (Angeles, 2005; Wu *et al.*, 2006). Diffusion of innovation theory also identified that compatibility is a consideration for technology acceptance (Rogers, 2003; Moore *et al.*, 1991). Therefore, RFID must be able to work with current technology in an organisation, and this is done by integrating RFID systems with other systems to provide additional benefits.

5.2.7.5 Authentication challenges

In some circumstances, it would be useful to be able to verify or authenticate that the information read from a tag, or the item itself to which the tag is attached, is genuine. For example, a tamper-proof tag with an electronic authentication system could help isolate goods that are not authentic, such as pirated media or substitute food products. Currently, basic RFID tags provide only a fixed identifier, which is used to query a database for information about the tagged item. There is not necessarily any system in place to verify that the tag providing the number is not a copy or a fake (Juels, 2006; Staake, Thiesse and Fleisch, 2005; Smith, 2005). This is similar to sticking a fake barcode on an item.

5.3 Summary of Barriers

Table 10 includes all adoption barriers informed by the literature review, and indicates the commonality of adoption concerns across the various research groups and authors. The following codes are used to represent different authors in Table 10:

A: Montgomery (2006)
B: Aberdeen Group (2005)
C: Swanton (2005)
D: VDC (2006)
E: ATK and KSA (2004)
F: Davison and Smith (2005)
G: Wu, Nystrom, Lin and Yu (2006)
H: Seymour, Lambert-Porter and Willuweit (2007)
I: Cooke (2005)
J: Walker (2004)
K: Eckfeldt (2005)
L: Commonwealth of Australia (2006)
M: Leong, NG and Cole (2006)
N: Asif and Mandviwalla (2005)
O: Michael and McCathie (2005)
P: Huber, Michael and McCathie (2007)
Q: Angeles (2005)
R: Juels (2006)
S: Staake, Thiesse and Fleisch (2005)

Barriers to RFID adoption (categories)	**Authors and Research Group**																		
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**
Authentication challenges																		X	X
Awaiting next generation of offerings				X															
Consumer privacy concerns					X	X													
Current technology in place is satisfactory/existing technologies will work faster and better			X	X		X													
Customers and suppliers won't use it	X							X											
Health challenges											X	X							
High cost of hardware/infrastructure		X	X	X	X		X	X											
High cost of software, integration, service, and support			X	X			X	X											
High cost of tags	X	X			X	X	X	X											
High degree of business process change required					X	X		X											
Implementation challenges													X	X	X				
Integration challenges							X									X	X		
Lack of awareness	X			X															

Lack of application requirements/Not applicable or relevant				X				X											
Lack of business case or unconvinced business case	X					X													
Lack of customer demands			X					X											
Lack of senior management support						X		X											
Lack of skilled personnel								X	X	X									
Lack of standards	X	X	X	X	X	X	X	X											
Need to fix data synchronisation first						X													
No compelling value proposition		X						X											
No identifiable business need						X													
Not suitable for product assortment						X													
Poor tag read rates/tag reader accuracy		X			X		X	X											
Products not optimal to RFID			X																
Security					X			X											
The data would swamp business						X													
Unclear on benefits of RFID				X				X											
Unclear ROI	X		X	X			X												

Table 10: Summary of barriers to RFID adoption

5.4 Conclusion

RFID technology is faced with many barriers that limit the potential adopters in the market, currently resulting in a low rate of adoption, particularly in the retail sector. These barriers constitute key contribution to the slow uptake of RFID technology, and for that reason need to be understood. Categories of different barriers need to be considered in the adoption of RFID. These categories do not influence RFID adoption in isolation, but they influence one another in order to affect the decision-making on the uptake of RFID adoption.

The barriers identified show that most retailers have concerns relating to the following challenges:

- technical constraints
- cost challenges
- standards challenges
- return on investment challenges
- privacy challenges
- security challenges
- lack of awareness and education
- business process change challenges
- integration challenges
- success of current technology in use
- implementation challenges
- health challenges

The factors that need to be considered and the characteristics of RFID adoption projects differ significantly between different application and regions (Fish and Forrest, 2007). Consequently, an approach towards the barriers of RFID adoption in the context of the South African retail sector needs to be explored.

Chapter 6

Proposed Conceptual Framework of the Barriers of RFID Adoption in the South African Retail Sector

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This chapter uses the investigation into diffusion of innovation in Chapter 4 and the barriers to RFID adoption in Chapter 5 as a basis for a model describing the barriers to RFID technology in the South African retail sector. The chapter presents a conceptual framework in detail. This chapter also details the hypotheses that form the basis of this empirical study.

6.1 Introduction

In the literature review, a number of RFID adoption challenges were identified. These challenges are believed to potentially hamper RFID adoption. The analysis of these challenges revealed that none of the authors covered all the aspects of the adoption constraints thoroughly. In this chapter a conceptual framework of the barriers to RFID technology in the South African retail sector is proposed. This framework covers the adoption challenges extensively.

6.2 Analysis of diffusion of innovation constructs and RFID adoption barriers

Chapters 4 and 5 identified various factors believed to impact the adoption of an innovation in general and then specifically focused on RFID technology.

6.2.1 Technological constraints

Numerous adoption challenges identified by many authors and research firms can be categorised under technological constraints. While some factors relate to aspects of the technology itself, others relating to aspects associated with RFID technology, such as people constraints and environmental constants. The following factors have been identified under the category of technological constraints:

- Lack of application required and not applicable or relevant
- Product not optimal to RFID identification
- Perceived usefulness
- Relative advantage
- No compelling value proposition
- Current technology in place is satisfactory or other technology will work faster and better
- Lack of business case or unconvinced business case
- Outcome expectations
- Lack of global standards
- Not suitable for product assortment
- Poor tag read rates or poor tag reader accuracy
- The data would swamp the business/data overload
- Complexity of technology.

6.2.1.1 Lack of technological usefulness and advantageousness

According to Swanton (2005), products not suited to RFID could be considered as one of barriers to the adoption of RFID technology, and this simply implies that RFID technology might not be appropriate for some products. This view is supported by VDC (2006), as they discovered that the lack of application required, is a factor that influences the adoption of RFID technology. If the technology cannot be utilised or is not useful to the business, then retailers are not interested. VDC (2006) agree with Davis (1989) and Davis *et al.* (1989) in that the perceived usefulness of a technology is a decisive factor in the adoption of that technology. Furthermore, Rogers (2003) indicates the importance of relative advantage, in that retailers will decide to adopt RFID based on the fact that the technology can provide additional benefits to those technologies currently in use. Coincidently, the Aberdeen Group (2005) suggested that if most companies believe RFID technology does not provide any compelling value proposition to its existing business environment, they will not consider using the technology. Additionally, Davison and Smith (2005) also revealed that if current technology in place is satisfactory and actually works faster and better than RFID, then again, there is no need for RFID adoption.

By rationalising the six factors identified in the previous paragraph, the lack of its technological usefulness and advantages relevant to current technology could be considered applicable to RFID technology adoption. However, according to Swanton (2005) and Davison and Smith (2005), only nine percent and twenty percent of the respondents, in their respective studies, who believe that RFID technology is not relevant to their business or is not useful in their situation, whereas most of the other respondents are more favourably disposed towards the technology. Brown and Russell (2007) have affirmed that several South African retailers consider RFID technology useful and believe it would be advantageous to their business context. Hence this could be considered as a barrier factor for RFID adoption, but is not considered to be a key barrier factor.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 1: Lack of technological usefulness and advantageousness

H_{01}: Lack of technological usefulness and advantage is not a barrier to RFID adoption in the retail sector

H_{11}: Lack of technological usefulness and advantageousness is a barrier to RFID adoption in the retail sector

6.2.1.2 Lack of a business case

Lack of business case or an unconvincing business case is another barrier factor identified in the literature review. According to Montgomery (2006) and Davison and Smith (2005), over one-third of the respondents in the retail sector believe that the business case for RFID adoption is inadequate. This view is supported by Brown and Russell (2007), who noted that currently there are no retailers in South Africa that have either carried out a pilot study or implemented RFID technology. As a result, there is no business case available for RFID adoption in the South African retail sector. Thus, the lack of business case will be an important barrier to RFID adoption in the South African retail sector. This point is also confirmed by Compeau *et al.* (1999), who discovered that individual behaviour or organisational behaviour is affected by the expected outcome from a decision. Therefore, without a convincing business case, there are numerous uncertainties that can seriously impact a business. Thus retailers are currently not willing to adopt RFID.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 2: Lack of a business case

H_{02}: Lack of a business case is not a barrier to RFID adoption in the retail sector

H_{12}: Lack of a business case is a barrier to RFID adoption in the retail sector

6.2.1.3 Lack of global standards

The majority of authors and research firms have identified the lack of global standards to be a factor influencing the adoption of RFID. While there are several RFID standards available that have been used by different vendors, there are difficulties in exchanging data across the supply chain. However, the lack of global standards does not seem to be the prominent barrier in the retail sector. This view is supported by

Montgomery (2006), who's research revealed that the lack of global standards is the least significant factor and has the lowest score of only 24 percent. Brown and Russell (2007) agree with Montgomery (2006), and argue that inconsistency in RFID standards is not an influential factor in the South African retail sector. Many respondents recognise the importance of standards, but do not regard standards as a critical factor holding back RFID adoption. As a result, while global standards are considered one of the barriers to RFID adoption, they might not be considered a key factor.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 3: Lack of global standards

H_{03}: Lack of global standards is not a barrier to RFID adoption in the retail sector

H_{13}: Lack of global standards is a barrier to RFID adoption in the retail sector

6.2.1.4 Not suitable for product assortment

RFID technology's suitability for product assortment in the retail sector is another concern (Davison and Smith, 2005). In Davison's research, almost one-quarter of respondents from the retail sector in the U.S., Canada, U.K., Germany and France believed that RFID is not suitable for product assortment. Therefore, it is a factor to be included in the framework, to be tested in the context of the South African retail sector.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 4: Not suitable for product assortment

H_{04}: RFID technology is suitable for product assortment in the retail sector

H_{14}: RFID technology is not suitable for product assortment in the retail sector

6.2.1.5 Poor tag reader accuracy and read rate

According to the Aberdeen Group (2005), as well as ATK and KSA (2004), poor tag read rates and poor tag reader accuracy is considered to be a technical barrier for RFID adoption in the retail sector. A retailer needs high accuracy both in stock control and at point of sale (POS) terminals for efficiency and effectiveness in data capturing and other services. With low accuracy reading, RFID would be unreliable

and would cause major losses. Retailers therefore consider tag reader accuracy as a barrier.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 5: Poor tag reader accuracy and read rate

H_{05}: Poor tag reader accuracy and read rate is not a barrier to RFID adoption in the retail sector

H_{15}: Poor tag reader accuracy and read rate is a barrier to RFID adoption in the retail sector

6.2.1.6 Large amount of data would swamp the business

While retailers may be concerned with data swamping or managing the large amount of data generated by an RFID system, Davison and Smith (2005) revealed that only seven percent of respondents where concerned about this. In fact, Brown and Russell (2007) suggested that retailers may actually enjoy the advantage that the capturing of additional data may bring. Hence, data swamping is a factor to be considered but is believed to be insignificant compared to other adoption barriers.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 6: Large amount of data would swamp the business

H_{06}: Data overflow generated by RFID technology is not a barrier to RFID adoption in the retail sector

H_{16}: Data overflow generated by RFID technology is a barrier to RFID adoption in the retail sector

6.2.1.7 Complexity of technology

Complexity of technology is a factor identified by Rogers (2003) and Moore *et al.* (1991). According to them, any innovation such as RFID technology should be easy to use and as simple as possible, as a result, lowering the constraints for business utilisation. Brown and Russell (2007) agree with Rogers (2003) and Moore *et al.* (1991); in addition, they revealed that most South African retailers do not believe RFID technology to be too complex to integrate, implement and use. The authors did recognise that extensive business process changes are required. Therefore,

Complexity of technology is a more favourable factor, but will still be included in the framework to confirm or contradict this belief.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 7: Complexity of technology

H_{07}: Complexity of technology is not a barrier to RFID adoption in the retail sector

H_{17}: Complexity of technology is a barrier to RFID adoption in the retail sector

From the above study, table 11 has been constructed to provide an overview of RFID adoption barriers in the category of technological constraints.

Category	Factor Analysis of Perceived RFID Barriers
Technological constraints	Lack of technological usefulness and advantageousness
	Lack of a business case
	Lack of global standards
	Not suitable for product assortment
	Poor tag reader accuracy and read rate
	Large amount of data would swamp the business
	Complexity of technology

Table 11: Technological constraints for RFID adoption in the retail sector

6.2.2 Cost and ROI constraints

A number of adoption challenges identified by many authors and research firms can be categorised under the cost and ROI constraints. These are listed below:

- High cost of hardware and infrastructure
- High cost of software, integration, service, and support
- High cost of tags
- Unclear ROI

6.2.2.1 High cost constraints

According to the Aberdeen Group (2005), Swanton (2005), VDC (2006) and ATK and KSA (2004), one of the barriers to RFID adoption is the high cost of hardware and infrastructure. In particular, a study done by ATK and KSA (2004) revealed that almost 70 percent of retail respondents considered the cost of equipment, including hardware and infrastructure, to be very high. Therefore, the high cost of hardware and infrastructure is a critical barrier for RFID adoption.

Swanton (2005) and VDC (2006) have also identified the high cost of software, integration, service, and support as a challenge for RFID adoption, since it is an essential part of the RFID adoption process. Brown and Russell (2007) discovered a number of South African retailers concerned about the high costs associated with RFID adoption. These costs include RFID software, integration with current systems, services and support provided by consulting firms and equipment providers. Therefore, these high costs are considered to be an important barrier factor for RFID adoption.

Furthermore, the majority of the authors have identified the high cost of tags as a critical deterrent in the adoption of RFID technology. Given that a tag is normally attached to every single product, the quantity required is high. Thus, the high cost of tags has a negative impact on the utilisation of RFID technology in the retail sector. Brown and Russell (2007) also noted that costs associated with RFID technology are a key factor to consider in the uptake of RFID technology. In particular, the high tag price is considered to be one of the major determinants. As a result, the high cost of tags is believed to be negatively impacting the adoption of RFID technology in the retail sector and is a fundamental factor to be included in the framework.

While each of these three factors play an important role in contributing to the overall high costs associated with RFID adoption, individually, each factor presents its own constraints. Thus, the framework includes each of the three cost factors separately in an attempt to establish an in-depth understanding of the most critical factors.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 8: The high cost of hardware and infrastructure

H_{08}: The high cost of hardware and infrastructure is not a barrier for RFID adoption in the retail sector

H_{18}: The high cost of hardware and infrastructure is a barrier for RFID adoption in the retail sector

Hypothesis Set 9: The high cost of software, integration, service, and support

H_{09}: The high cost of software, integration, service, and support is not a barrier for RFID adoption in the retail sector

H_{19}: The high cost of software, integration, service, and support is a barrier for RFID adoption in the retail sector

Hypothesis Set 10: The high cost of tags

H_{010}: The high cost of tags is not a barrier to RFID adoption in the retail sector

H_{110}: The high cost of tags is a barrier to RFID adoption in the retail sector

6.2.2.2 Unclear ROI

A number of authors have reported that unclear return on investment (ROI) is an adoption barrier to RFID technology. According to Montgomery (2006), a third of the respondents believe that ROI is not clear within RFID adoption, resulting in uncertainty as to the cost-benefit of the technology. VDC (2006) have the same opinion, and suggest that unclear ROI is a factor holding back widespread adoption. Therefore, unclear ROI is considered to be an influential factor in deciding on the uptake of RFID technology.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 11: Unclear ROI

H_{011}: Unclear ROI is not a barrier for RFID adoption in the retail sector

H_{111}: Unclear ROI is a barrier for RFID adoption in the retail sector

Table 12 has been constructed based on the above study to provide an overview of RFID adoption barriers in the category of cost and ROI constraints.

Category	Factor Analysis of Perceived RFID Barriers
Cost and ROI constraints	The high cost of hardware and infrastructure
	The high cost of software, integration, service, and support
	The high cost of tags
	Unclear ROI

Table 12: Cost and ROI constraints for RFID adoption in the retail sector

6.2.3 Privacy and security constraints

Two of the most commonly recognised challenges in the adoption of RFID technology are privacy and security constraints. The factors identified in this category are:

- Customer privacy concerns
- Security concerns

6.2.3.1 Customer privacy concerns

According to ATK and KSA (2004), two-thirds of the retailers are concerned with customer privacy when using RFID tags on their product, since most customers do not wish to expose their personal information to others. Therefore, retailers might think twice before adopting RFID systems. Davison and Smith (2005) share the same opinion, and discovered that retailers are worried about privacy issues related to RFID technology and the impact it has on its customers and the business. As a result, customer privacy is believed to be an important factor to be included in the framework.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 12: Customer privacy concerns

H_{012}: Customer privacy concerns are not a barrier to RFID adoption in the retail sector

H_{112}: Customer privacy concerns are a barrier to RFID adoption in the retail sector

6.2.3.2 Security concerns

While ATK and KSA (2004) identified security concerns as another issue associated with RFID technology, their research revealed that only seventeen percent of respondents view security as a barrier factor in RFID adoption. The majority of respondents consider RFID systems to be used mostly for internal stock control and the tracking of goods between different premises, therefore, security is not the main concern. Thus, security is not considered a crucial factor in the retail sector.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 13: Security concerns

H_{013}: Security concerns are not a barrier to RFID adoption in the retail sector

H_{113}: Security concerns are a barrier to RFID adoption in the retail sector

Table 13 has been constructed based on the above study to provide an overview of RFID adoption barriers in the category of privacy and security constraints.

Category	Factor Analysis of Perceived RFID Barriers
Privacy and security constraints	Customer privacy concerns
	Security concerns

Table 13: Privacy and security constraints for RFID adoption in the retail sector

6.2.4 Implementation constraints

When adopting RFID systems in the retail sector, it is essential to consider some of the implementation constraints associated with the technology. Some of the challenges identified under this category are:

- Integration
- Compatibility
- Implementation
- Authentication
- Data synchronisation

6.2.4.1 Compatibility and integration with other technology

According to Rogers (2003) and Moore *et al.* (1991), compatibility is an essential factor in determining the acceptance of a new technology among different organisations. RFID technology should be easily compatible with current systems, in order to encourage retailers to adopt RFID systems. Shister (2005) suggests that integration between RFID and organisational systems is complex and difficult. He concurs with Roger (2003) and Moore *et al.* (1991) that integration must be considered when adopting RFID systems. Thus compatibility and integration are two similar ideas, which can be combined into a single factor to be included in the framework.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 14: Compatibility and integration with other technology

H_{014}: Compatibility and integration of RFID with other technology is not a barrier to RFID adoption in the retail sector

H_{114}: Compatibility and integration of RFID with other technology is a barrier to RFID adoption in the retail sector

6.2.4.2 Implementation Challenges

An implementation challenge is a major factor to be included in this category. According to Leong *et al.* (2006), Asif *et al.* (2005) and Michael and McCathie (2005), there are a number of implementation challenges for RFID adoption, such as the way that the technology functions under certain environmental conditions. Implementation challenges may influence some retailers to hold back on their RFID adoption. Therefore, it can be considered as a single factor for the adoption of RFID technology.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 15: Implementation Challenges

H_{015}: Implementation Challenges are not a barrier to RFID adoption in the retail sector

H_{115}: Implementation Challenges are a barrier to RFID adoption in the retail sector

6.2.4.3 The need to address data synchronisation first

According to Davison and Smith (2005), before implementing RFID systems, there is a preparation phase necessary to get an organisation ready for RFID adoption. This includes the need to address data synchronisation prior to installing the actual RFID system. The data captured by RFID systems needs to be reflected immediately on the other systems at various locations, and without synchronising data, data exchange between different locations will be outdated and unreliable. Therefore, some retailers believe that this is also a barrier to the adoption of RFID technology. The additional procedures required before the actual adoption might cause some retailers to hesitate in adopting RFID technology. As a result, the need to fix data synchronisation first, although not a critical factor, is another factor in the implementation category.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 16: The need to address data synchronisation first

H_{016}: The need to address data synchronisation is not a barrier to RFID adoption in the retail sector

H_{116}: The need to address data synchronisation is a barrier to RFID adoption in the retail sector

6.2.4.4 RFID authentication challenges

Juels (2006) identified tag authentication as a challenge to RFID utilisation. Currently there is no authentication mechanism available for general use, and companies need to develop their own method for authenticating tags on a product, or use a consultant to assist with implementing authentication mechanisms on their RFID systems and tags. This factor is included in the framework to test if this is still the case.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 17: RFID authentication challenges

H_{017}: RFID authentication challenges are not a barrier to RFID adoption in the retail sector

H_{117}: RFID authentication challenges are a barrier to RFID adoption in the retail sector

Table 14 has been constructed to reflect the RFID adoption barriers in the category of implementation constraints.

Category	Factor Analysis of Perceived RFID Barriers
Implementation constraints	Compatibility and integration with other technology
	Implementation challenges
	The need to fix data synchronisation first
	RFID authentication challenges

Table 14: Implementation constraints for RFID adoption in the retail sector

6.2.5 Organisational constraints

There are many organisational factors that influence the adoption of RFID technology in the retail sector. This is particularly true when a retailer is reluctant to change or adopt a new technology. This creates huge hurdles for RFID adoption in the retail environment. Some of the organisational barrier factors are:

- High degree of business process change required
- Lack of awareness
- No identifiable business needs

6.2.5.1 A high degree of business process change required

According to ATK and KSA (2004) and Davison and Smith (2005), many retailers are concerned about the high degree of business process change required when implementing and utilising RFID in their stores and warehouses. While most retailers are comfortable with the business process they have in place, it is difficult for RFID technology to integrate into their processes without making extensive changes. Brown and Russell (2007) agree with this point and suggest that most South African retailers are concerned about the complexity of business change required by RFID implementation. Thus it is a critical factor to be included in the framework.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 18: A high degree of business process change required

H_{018}: A high degree of business process change is not a barrier to RFID adoption in the retail sector

H_{118}: A high degree of business process change is a barrier to RFID adoption in the retail sector

6.2.5.2 Lack of awareness

Lack of awareness is another barrier to RFID adoption in the retail sector. As long as retailers and top managers are unaware of the technology or know little about it, it is unlikely that retailers will become familiar with the technology. According to Montgomery (2006) and VDC (2006), the majority of retailers are unaware of or know little about RFID, causing the slow uptake of RFID technology in the retail sector. Brown and Russell (2007) further confirmed this and suggest that it is the responsibility of the IT department to inform top managers and the board of directors about RFID technology. Therefore, one of the major barriers is the lack of awareness, particularly for small medium retailers, where technological information is not well received.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 19: Lack of awareness

H_{019}: Lack of awareness is not a barrier to RFID adoption in the retail sector

H_{119}: Lack of awareness is a barrier to RFID adoption in the retail sector

6.2.5.3 A lack of identifiable business needs

According to Davison and Smith (2005), one of the barriers to RFID technology is not having an identifiable business need. Some retailers believe their businesses do not need RFID technology, and therefore, are not considering adopting RFID. About ten percent of the respondents agree with this view, while the majority of the respondents believe that RFID will improve efficiency and effectiveness when performing business operations. Therefore concerns surrounding the lack of an identifiable business need are not considered a major RFID adoption barrier.

The following hypothesis has been formulated:

Hypothesis Set 20: A lack of identifiable business needs

H_{020}: A lack of identifiable business needs is not a barrier to RFID adoption in the retail sector

H_{120}: A lack of identifiable business needs is a barrier to RFID adoption in the retail sector

Table 15 has been constructed based on the above study to provide an overview of RFID adoption barriers in the category of organisational constraints.

Category	Factor Analysis of Perceived RFID Barriers
Organisational constraints	High degree of business process change required
	Lack of awareness
	A lack of identifiable business needs

Table 15: Organisational constraints for RFID adoption in the retail sector

6.2.6 People constraints

As discussed in the diffusion of innovation chapter, people are considered to be a major influence on the decision to adopt RFID technology. Their opinion will directly influence retailers to use RFID in their business or not. Therefore, understanding how people perceive RFID technology is an essential criterion in determining the adoption constraints. Some of the people constraints are:

- Customers and suppliers won't use it
- Lack of customer demand
- Lack of senior management support
- Attitudes towards using technology
    - Attitude toward behaviour
    - Affect toward use
    - Affect
- Lack of skilled personnel
- Perceived behavioural control

6.2.6.1 The unwillingness of the customer and supplier to use it

Montgomery (2006) revealed that key customers and suppliers are reluctant to use RFID technology. Over a quarter of the respondents are reluctant to adopt RFID technology because associated suppliers are unwilling to use it, which has a major influence on retailers. If suppliers are unwilling to tag their products, retailers will have to tag products themselves. As a result, retailers then have to carry a heavy burden on the costs associated with tagging. Furthermore, if customers are unwilling to use RFID technology, then they might discontinue shopping in retail stores with RFID systems, resulting in reduced sales. Both Swanton (2005) and Montgomery (2006) believe that without customer demand for RFID technology, there is little motive for retailers to deploy RFID systems. Thus, these two factors are believed to be imperative in the process of decision making on RFID adoption, and should be included in the framework exploring the willingness by customers and suppliers to adopt RFID technology.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 21: The unwillingness of the customer and supplier to use it

H_{021}: The unwillingness of the customer and supplier to use RFID technology is not a barrier to RFID adoption in the retail sector

H_{121}: The unwillingness of the customer and supplier to use RFID technology is a barrier to RFID adoption in the retail sector

6.2.6.2 Lack of senior management support

The lack of senior management support is another factor thought to influence the adoption of RFID technology. According to Davison and Smith (2005), top senior management is not supportive of RFID adoption. A number of reasons have been put forward such as resistance to change or negative feelings towards the technology. Therefore, the up-take of RFID is slow. Taylor and Todd (1995b) and Thompson *et al.* (1991) have worried that an individual's negative attitude towards the technology could cause companies to hold back on their adoption, particularly, when that individual is a decision maker. Compeau *et al.* (1999) concurs with Taylor and Todd (1995b) and Thompson *et al.* (1991), discovering that the affect of an individual's liking has an impact on decisions. Brown and Russell (2007) agree with these views and believe that top management's attitude towards RFID technology has a direct

impact on RFID adoption. According to their research, most top managers in the South African retail sector show little to no support for RFID, and for those reasons, little has been done in the context of the South African retail sector. Thus, senior management support is believed to be a critical factor when exploring adoption constraints.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 22: Lack of senior management support

H_{022}: Lack of senior management support is not a barrier to RFID adoption in the retail sector

H_{122}: Lack of senior management support is a barrier to RFID adoption in the retail sector

6.2.6.3 Lack of skilled personnel

According to Cooke (2005), the lack of skilled personnel is a constraint in the adoption of RFID technology. Many retailers do not have an RFID specialist in their organisations, which results in these organisations experiencing difficulty in understanding RFID technology and associated matters. Taylor and Todd (1995b) holds a similar view, and suggests that perceived behavioural control indicates that the user should be qualified to make use of an innovation, and as a result, the user is more likely to adopt RFID technology, and vice versa. Brown and Russell (2007) found that in South Africa, most organisations, particularly retailers, lack the necessary technical personnel to integrate and deploy RFID systems in their business. Thus the lack of skilled personnel is explored as a potential barrier to RFID adoption in the retail sector.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 23: Lack of skilled personnel

H_{023}: Lack of skilled personnel is not a barrier to RFID adoption in the retail sector

H_{123}: Lack of skilled personnel is a barrier to RFID adoption in the retail sector

Table 16 has been constructed based on the above study to provide an overview of RFID adoption barriers in the category of people constraints.

Category	Factor Analysis of Perceived RFID Barriers
People constraints	The unwillingness of the customer and supplier to use it
	Lack of senior management support
	Lack of skilled personnel

Table 16: People constraints for RFID adoption in the retail sector

6.2.7 Environmental constraints

Environmental constraints are external barriers that influence the adoption of RFID technology. These barriers have either direct or indirect impact on the decisions to deploy RFID systems. They are:

- Social influence
  - Subject norm
  - Social factors
  - Image
- Facilitation conditions
- Effect of radio emissions on personal health

6.2.7.1 Social influence

One of the factors identified in Chapter 4 is the social influence impacting the uptake of a new technology. This also applies to the RFID context, since this factor mostly looks at how a senior manager's perception of RFID technology might change when influenced by some people, group or organisation that are important to him. According to Taylor and Todd (1995b), this is an important factor to be considered on how an external factor influences the decision to adopt or hold back on RFID implementation. Thompson *et al.* (1991) found that social factors such as legal legislation or other limitations can cause RFID implementation to be delayed or stopped. In addition, Moore *et al.* (1991) suggest that deploying RFID technology must not harm a retailer's reputation in the community, but according to Blanchard (2003), there are a number of protection groups who have protested against the use of RFID technology in the retail environment, resulting in some retailers holding back on

the adoption of RFID. Thus, social influence is a necessary factor to be used in determining the barrier to RFID adoption in the retail sector.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 24: Social influence

H_{024}: Social influence is not a barrier to RFID adoption in the retail sector

H_{124}: Social influence is a barrier to RFID adoption in the retail sector

6.2.7.2 The effect of radio emissions on personal health

According to Thompson *et al.* (1991), facilitative conditions should be considered when adopting RFID technology, and the two facilitation methods recognised are providing necessary specialists to assist in adoption and training, and providing a detailed business case to be used for RFID adoption. Given that all these methods can facilitate retailers in implementing RFID successfully, the facilitation conditions are then considered as criteria for RFID adoption. However, the framework already explores issues relating to skilled personnel and business case; therefore, facilitation conditions are not included in the framework to avoid repetition.

There are concerns about radio frequency emissions and the impact of RFID emissions on personal health. This is acknowledged by Eckfeldt (2005), who noted that a number of people are concerned about health and safety relating to so-called electromagnetic emission released by RFID systems. Therefore, the effect of radio emission on personal health is a factor to be included in the framework, in order to understand the perceptions of South African retailers regarding this issue.

Consequently, the following hypothesis has been formulated:

Hypothesis Set 25: The effect of radio emissions on personal health

H_{025}: The effect of radio emissions on personal health is not a barrier to RFID adoption in the retail sector

H_{125}: The effect of radio emissions on personal health is a barrier to RFID adoption in the retail sector

Table 17 has been constructed based on the above study to provide an overview of RFID adoption barriers in the category of environmental constraints.

Category	Factor Analysis of Perceived RFID Barriers
Environmental constraints	Social influence
	The effect of radio emissions on personal health

Table 17: Environmental constraints for RFID adoption in the retail sector

6.3 High-level description of the model

The framework for the adoption barriers for the South African retail sector is constructed based on the above studies. It comprises seven major categories that impact on the RFID adoption process. These seven major categories are:

- Technological constraints
- Cost and ROI constraints
- Privacy and security constraints
- Implementation constraints
- Organisational constraints
- People constraints
- Environmental constraints

Each of the categories consists of two or more barriers that affect the adoption of RFID technology in the retail sector.

6.4 Conceptual framework of the barriers of RFID adoption in the South African retail sector

The proposed conceptual framework of the barriers to RFID adoption focuses on South African retailers' perceptions regarding the adoption and use of RFID technology in the retail sector. The emphasis in this framework is on recognising and understanding the reasons retailers are holding back on the adoption of RFID technology.

A holistic approach has been taken to identifying the barriers of RFID adoption by exploring all the factors identified in the proceeding chapters. These factors have then been grouped into 7 common categories.

The proposed conceptual framework of the barrier of RFID adoption in the South African retail sector is illustrated below:

Area of Constraints	Factor Analysis of Perceived RFID Barriers
Technological	Lack of technological usefulness and advantageousness
	Lack of a business case
	Lack of global standards
	Not suitable for product assortment
	Poor tag reader accuracy and rates
	Large amount of data would swamp the business
	Complexity of technology
Cost and ROI	The high cost of hardware and infrastructure
	The high cost of software, integration, service, and support
	The high cost of tags
	Unclear ROI
Privacy and Security	Customer privacy concerns
	Security concerns
Implementation	Compatibility and integration with other technology
	Implementation challenges
	The need to fix data synchronisation first
	RFID authentication challenges
Organisational	A high degree of business process change required
	Lack of awareness
	A lack of identifiable business needs
People	The unwillingness of the customer and supplier to use it
	Lack of senior management support
	Lack of skilled personnel
Environment	Social influence
	The effect of radio emissions on personal health

Table 18: RFID adoption constraints perceived by retailers

6.5 Conclusion

This chapter described the potential barriers to RFID adoption, emanating from Chapter 4 and 5, thought to be relevant to the South African retail sector. A total of 25 hypotheses were formulated with a view to testing these hypotheses by means of a survey instrument (described in Chapter 7). Chapter 6 concluded with a conceptual framework consisting of 25 barriers placed into seven categories.

Chapter 7

Research Methodology

The previous chapter presented a proposed conceptual framework of the barriers of RFID adoption in the South African retail sector. This chapter explores the research methodology used to validate the framework proposed in Chapter 6, by investigating RFID adoption barriers perceived by SA retailers. The research design is explained, the hypotheses are defined, and the data collection method is also provided.

7.1 Introduction

The literature review focuses on empirical research and theoretical background that are relevant to this study. The purpose of this research is to provide information and insights to the technological and business communities in South Africa, and to help them to understand the potential of this rapidly growing technology (RFID) in the market place, particularly, understanding the constraints regarding RFID adoption in the South African retail sector.

This chapter describes the research methodology for investigating RFID adoption barriers in the South African retail sector. A quantitative research methodology is adopted as the most appropriate approach. Most of the research work, investigation and data collections were done based on a survey of South African retail organisations, who have acknowledged an awareness of RFID.

7.2 Quantitative Research Paradigm

The quantitative research paradigm is an investigation of a phenomenon by testing a theory that can be measured numerically and analysed statistically (Creswell, 1994). This paradigm is appropriate for an issue that is considered real or a fact that can be measured objectively, using for example, a questionnaire where the researcher remains independent of what is being studied and the research process deductive in nature (Creswell, 1994).

The quantitative paradigm used in this research was selected for the following reason: RFID, although not new in concept and application, remains untested within the South African retail sector. For that reason, any form of qualitative assessment such as a case study across two or three retail organisations would have been extremely difficult if not impossible. It was considered appropriate to try and measure the perceptions held by senior management and a variety of senior IT professionals across as many South African retail businesses as possible in an attempt to determine what the real adoption constraints of RFID technology are within South African retail.

7.3 Research Design

Research design is a systematic planning of the research, usually including what data to gather, from whom, how and when to collect and record the data, and ultimately how to analyse and interpret the data obtained. The purpose is to formulate a strategy to resolve the research question.

A number of respondents were surveyed about their perceptions of many aspects of RFID adoption constraints pertinent to the proposed framework. A questionnaire was developed as the data collection tool to capture the perceptions held by various senior managers and IT professionals in the retail sector. The main objective was to explore the validity of the proposed framework of current perceptions amongst different retailers, and 25 hypotheses, described below, were constructed to validate these RFID adoption barriers.

7.4 The Hypotheses

The study is aimed at investigating RFID adoption constraints in the retail industry. Numerous research hypotheses were formulated based on the proposed conceptual framework, and they are detailed below:

7.4.1 Technological

7.4.1.1 Hypothesis Set 1: Lack of technological usefulness and advantageousness

H_{01}: Lack of technological usefulness and advantageousness is not a barrier to RFID adoption in the retail sector

H_{11}: Lack of technological usefulness and advantageousness is a barrier to RFID adoption in the retail sector

7.4.1.2 Hypothesis Set 2: Lack of a business case

H_{02}: Lack of a business case is not a barrier to RFID adoption in the retail sector

H_{12}: Lack of a business case is a barrier to RFID adoption in the retail sector

7.4.1.3 Hypothesis Set 3: Lack of global standards

H_{03}: Lack of global standards is not a barrier to RFID adoption in the retail sector

H_{13}: Lack of global standards is a barrier to RFID adoption in the retail sector

7.4.1.4 Hypothesis Set 4: Not suitable for product assortment

H_{04}: RFID technology is suitable for product assortment in the retail sector

H_{14}: RFID technology is not suitable for product assortment in the retail sector

7.4.1.5 Hypothesis Set 5: Poor tag reader accuracy and read rate

H_{05}: Poor tag reader accuracy and read rate is not a barrier to RFID adoption in the retail sector

H_{15}: Poor tag reader accuracy and read rate is a barrier to RFID adoption in the retail sector

7.4.1.6 Hypothesis Set 6: Large amount of data would swamp the business

H_{06}: Data overflow generated by RFID technology is not a barrier to RFID adoption in the retail sector

H_{16}: Data overflow generated by RFID technology is a barrier to RFID adoption in the retail sector

7.4.1.7 Hypothesis Set 7: Complexity of technology

H_{07}: Complexity of technology is not a barrier to RFID adoption in the retail sector

H_{17}: Complexity of technology is a barrier to RFID adoption in the retail sector

7.4.2 Cost and ROI

7.4.2.1 Hypothesis Set 8: The high cost of hardware and infrastructure

H_{08}: The high cost of hardware and infrastructure is not a barrier for RFID adoption in the retail sector

H_{18}: The high cost of hardware and infrastructure is a barrier for RFID adoption in the retail sector

7.4.2.2 Hypothesis Set 9: The high cost of software, integration, service, and support

H_{09}: The high cost of software, integration, service, and support is not a barrier for RFID adoption in the retail sector

H_{19}: The high cost of software, integration, service, and support is a barrier for RFID adoption in the retail sector

7.4.2.3 Hypothesis Set 10: The high cost of tags

H_{010}: The high cost of tags is not a barrier to RFID adoption in the retail sector

H_{110}: The high cost of tags is a barrier to RFID adoption in the retail sector

7.4.2.4 Hypothesis Set 11: Unclear ROI

H_{011}: Unclear ROI is not a barrier for RFID adoption in the retail sector

H_{111}: Unclear ROI is a barrier for RFID adoption in the retail sector

7.4.3 Privacy and Security

7.4.3.1 Hypothesis Set 12: Customer privacy concerns

H_{012}: Customer privacy concerns are not a barrier to RFID adoption in the retail sector

H_{112}: Customer privacy concerns are a barrier to RFID adoption in the retail sector

7.4.3.2 Hypothesis Set 13: Security concerns

H_{013}: Security concerns are not a barrier to RFID adoption in the retail sector

H_{113}: Security concerns are a barrier to RFID adoption in the retail sector

7.4.4 Implementation

7.4.4.1 Hypothesis Set 14: Compatibility and integration with other technology

H_{014}: Compatibility and integration of RFID with other technology is not a barrier to RFID adoption in the retail sector

H_{114}: Compatibility and integration of RFID with other technology is a barrier to RFID adoption in the retail sector

7.4.4.2 Hypothesis Set 15: Implementation Challenges

H_{015}: Implementation Challenges are not a barrier to RFID adoption in the retail sector

H_{115}: Implementation Challenges are a barrier to RFID adoption in the retail sector

7.4.4.3 Hypothesis Set 16: Need to address data synchronisation first

H_{016}: The need to address data synchronisation is not a barrier to RFID adoption in the retail sector

H_{116}: The need to address data synchronisation is a barrier to RFID adoption in the retail sector

7.4.4.4 Hypothesis Set 17: RFID authentication challenges

H_{017}: RFID authentication challenges are not a barrier to RFID adoption in the retail sector

H_{117}: RFID authentication challenges are a barrier to RFID adoption in the retail sector

7.4.5 Organisational factors

7.4.5.1 Hypothesis Set 18: A high degree of business process change required

H_{018}: A high degree of business process change is not a barrier to RFID adoption in the retail sector

H_{118}: A high degree of business process change is a barrier to RFID adoption in the retail sector

7.4.5.2 Hypothesis Set 19: Lack of awareness

H_{019}: Lack of awareness is not a barrier to RFID adoption in the retail sector

H_{119}: Lack of awareness is a barrier to RFID adoption in the retail sector

7.4.5.3 Hypothesis Set 20: A lack of identifiable business needs

H_{020}: A lack of identifiable business needs is not a barrier to RFID adoption in the retail sector

H_{120}: A lack of identifiable business needs is a barrier to RFID adoption in the retail sector

7.4.6 People

7.4.6.1 Hypothesis Set 21: The unwillingness of the customer and supplier to use it

H_{021}: The unwillingness of the customer and supplier to use RFID technology is not a barrier to RFID adoption in the retail sector

H_{121}: The unwillingness of the customer and supplier to use RFID technology is a barrier to RFID adoption in the retail sector

7.4.6.2 Hypothesis Set 22: Lack of senior management support

H_{022}: Lack of senior management support is not a barrier to RFID adoption in the retail sector

H_{122}: Lack of senior management support is a barrier to RFID adoption in the retail sector

7.4.6.3 Hypothesis Set 23: Lack of skilled personnel

H_{023}: Lack of skilled personnel is not a barrier to RFID adoption in the retail sector

H_{123}: Lack of skilled personnel is a barrier to RFID adoption in the retail sector

7.4.7 Environment

7.4.7.1 Hypothesis Set 24: Social influence

H_{024}: Social influence is not a barrier to RFID adoption in the retail sector

H_{124}: Social influence is a barrier to RFID adoption in the retail sector

7.4.7.2 Hypothesis Set 25: The effect of radio emissions on personal health

H_{025}: The effect of radio emissions on personal health is not a barrier to RFID adoption in the retail sector

H_{125}: The effect of radio emissions on personal health is a barrier to RFID adoption in the retail sector

7.5 Survey Methodology

The survey is a non-experimental, descriptive research method. Surveys can be useful to collect data on phenomena that cannot be directly observed, such as one's perceptions. A survey is used extensively to assess attitudes and characteristics towards a subject, and in this research, the purpose is to understand the perceptions of RFID adoption barriers by South African retailers.

There are two basic types of surveys: cross-sectional surveys and longitudinal surveys. This research utilises the cross-sectional survey, since it is used to gather information on a population at a single point in time, In this case, data were gathered around October 2007. The survey questionnaire was considered to be the most appropriate mechanism for data collection and was formulated based on the hypothesis identified in this chapter. Each hypothesis was addressed individually in the questionnaire.

7.6 Design of the Questionnaire

The questionnaire is designed in such a way as to ensure the questions are:

- valid, that is, the questions measure what the research is intended to measure
- reliable, that is, the questions would yield the same results if administered at different times or to different samples
- unbiased, that is, the questions are written in such a way that people are willing and able to provide accurate answers.

In addition, the questionnaire is constructed to achieve the following:

- Questions are not too long since most senior managers or IT personnel do not have a great deal of time to complete the survey.
- Respondents can easily answer based on their knowledge and experience
- Questions are simple, specific, and sufficiently well-defined so that all respondents will interpret them in the same way.
- Questions contain no words or phrases which could bias respondents to answer one way over another.
- It is clear to respondents exactly what types of answers are appropriate.
- Questions should be focused on a single topic rather than containing multiple topics that would confuse the respondent.

The survey questionnaire was not borrowed or adapted from any other researcher, and therefore, originality of the questionnaire is achieved with specific focus on RFID adoption constraints.

7.6.1 Format and presentation

The format and presentation is designed to ensure the questionnaire is easy to complete without error. It is also specifically designed to be as standard as possible, and different questions are presented in the same format in order to reduce the time and effort required from the respondent. A sample of the online survey can be found in Appendix B. The format of the questionnaire is as follows:

- It begins with some background information on RFID technology and instructions about the survey.
- Personal and organisational details about the respondents are gathered. This is followed by questions on the status of RFID technology in their organisation. Furthermore, the respondent's familiarity with RFID technology is also asked about. Questions are either multiple choice or open-ended format, where respondents can answer in their own words, such as the name and organisation their represent.
- The body of the questionnaire is designed according to the hypotheses that were formulated based on the proposed conceptual framework in the previous chapter. Each hypothesis is used to construct one or more questions that would be used to measure and answer that particular hypothesis. The questions are constructed in the order of the hypothesis for easy analysis and are grouped under specific categories. These questions are based on a five point Likert scale, ranging from: 'strongly disagree', 'disagree', 'neutral', 'agree', to 'strongly agree'.
- At the end of the questionnaire, there are open-ended questions for comments, and respondents are also given the opportunity to enter contact details and to request feedback on research findings.

7.7 Data Collection Procedure

The questionnaire was distributed via the Internet using an open source survey system called "PHP Easy Survey Package", which allows the researcher to create surveys, manage surveys, gather results and view statistics.

The questionnaire was administered in the following way:

- The researcher obtained a list of potential organisations from the Consumer Goods Council of South Africa (CGCSA) and the South African Chamber of Business (SACOB). The researcher also identified some of the major retailers that were not included in the CGCSA and SACOB lists.
- IT personnel and senior managers of each retail organisation were telephoned and asked whether they would be prepared to participate in the survey. These individuals were specifically selected to participate in the survey based on the criteria discussed later.
- Once respondents had confirmed they would participate, an email was sent to them immediately, explaining the purpose of the survey, and with a URL link embedded in the email. In addition, a cover letter that briefly introduces the study and explains why it is important was also attached to the email.
- When respondents clicked on the link, they were automatically forwarded to the online questionnaire.
- A follow-up letter was sent if the respondents had not completed the survey within 10 days. This was to ensure that a high response rate was achieved.

7.8 Pilot study

According to Polit and Hungler (1997), a pilot study is a trial run to determine whether an instrument solicits the type of information anticipated by the researcher. A pilot study was performed on the survey. Data were collected from 5 different individuals around the world to ensure that:

- The survey was accessible
- Questions were clear and precise
- The layout was logical and simple to follow
- The length of the survey was not too long, to avoid survey fatigue
- Data obtained were accurately captured and stored in the database.

Feedback was then gathered from each individual on their experience of completing the survey. Some of the comments and feedback resulted in minor refinements to the survey. Comments and changes are listed below:

- The survey should be displayed only on a single page for respondents to scroll down, rather than divided into 4 pages. This was for easy viewing, and also to encouraged respondents to complete the survey, given that they would know the length of the survey up-front.
- A compulsory question should be marked with a red asterix (*) to alert a respondent that a particular question had to be completed.
- The demographic profile of respondents was missing, and therefore, it was introduced to gain a better understanding of the respondent and their position in an organisation.
- A few questions were identified as confusing, and were subsequently rephrased.

7.9 Population and Sample

The study was conducted within the quantitative paradigm and hence probability sampling techniques would normally be used. Two purposeful sampling strategies were selected, namely criterion and judgemental sampling, where the judgemental sample is based on who the researcher thinks would be appropriate for the study. This is used primarily when there are limited numbers of potential respondents that have expertise in the research area, hence the limited number of possible samples. Respondents from retail organisations had to meet the following criteria:

- The respondent had to belong to one of the major retailers in South Africa. A 'major retailer' in this research is defined as a retailer who has branches in most major cities in South Africa, particularly, those department stores in South Africa that are well known, such as Pick 'n Pay, Woolworths and Shoprite.
- The respondent had to either be the CIO, IT Director, Manager (IT manager is preferable) or senior staff member involved in technology strategy within the organisation.
- Only one respondent from each retail organisation was permitted to answer the questionnaire. This is because several organisations own more than one major

retailer in South Africa. It was believed that major strategic IT decisions such as whether or not to adopt RFID would be made at the parent company level. As an example, Massmart Holdings owns Game®, Dion®, Makro®, Builders Warehouse®, Builders Express®, Jumbo®, Shield® and Trade Department®. Therefore, it was considered preferable to ask the CIO of Massmart Holdings to participate in the survey, rather than IT managers or IT personnel at the retail branch level. A list of retails surveyed in this research can be found in Appendix A.

Given that many of the well known retailers in South Africa are owned by a few large holding companies and that IT strategy is usually driven by the holding company, it became evident that the sample size of retailers would be smaller than originally planned. A sample size of 30 was deemed realistic, as it would include most major South African retail organisations. The statistical testing chosen for this research was selected with this sample size in mind.

7.10 Data Analysis Procedure

The results of the statistical analysis are presented as follows:

- Tables, such as frequency distributions
- Graphs, such as histograms, bar diagrams and pie charts
- A result summary in terms of counts and percentages
- Statistical summaries in terms of mean, median, mode and standard deviation

A hypothesis was formulated for each question, and is subject to statistical analysis using an appropriate test. Answers to the questionnaire were measured on a five-point Likert scale, which is an interval scale, and appropriate for the Wilcoxon Signed Rank test. According to Hair, Anderson, Tatham and Black (1998), statistical tests work with counts of observations or the rank or each observation in the set of data is appropriate for an ordinal data. The Likert scale used in the questionnaire is an ordinal data, as a result, the Wilcoxon Signed Rank test was applied to responses for each question in order to establish validity. All statistical tests were one-tailed tests, that is, the set of values less than or greater than the critical value of the test, and the probability value (p-value) was established at 0.05 a priori (or equivalently to 5%).

The p-value is compared with the actual significance level of our test and, if it is smaller, the result is significant. That is, if the null hypothesis were to be rejected at the 5% significance level, this would be reported as "$p<0.05$". Small p-values suggest that the null hypothesis is unlikely to be true. The smaller it is, the more convincing is the rejection of the null hypothesis. It indicates the strength of evidence to say, reject the null hypothesis H_0, rather than simply concluding "Reject H_0" or "Do not reject H_0".

By setting the neutral null hypothesis as 3 within the five-point Likert scale, the Wilcoxon Signed Rank Test would establish for which question the neutral null hypothesis should be rejected. As these data are nonparametric, the Wilcoxon test was chosen over inappropriate parametric tests such as the t-test. The Likert scale is coded as follows to facilitate statistically analysis of the data using Statistica (Statsoft, Inc., 2007) and R (R Development Core Team, 2007).

Likert Scale	*Code*
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Table 19: Code Scheme used for Statistical Analysis

There are two Wilcoxon Signed Rank tests performed for each question. One is used to test if respondents agree with the statement, and the second one is used to test if respondents disagree with the statement. If both tests fail to reject null hypothesis, that means there is no conclusive evidence to determine whether the barrier factor tested is or is not a barrier to RFID adoption in the retail sector.

7.11 Response Rates and Confidentiality

Eighteen retailers were identified as major retailers in South Africa, based on the list obtained from the Consumer Goods Council of South Africa (CGCSA) and the South African Chamber of Business (SACOB). An additional 21 major retailers were identified and included in the list. The final list consisted of 39 retailers who were approached and asked to complete the online survey. Initially, telephonic contact was

made with each organisation to find the appropriate person to complete the survey. Most respondents agreed to participate in the survey and some refused. Finally, 33 completed surveys were collected.

Adequate measures were taken to protect the confidentiality of respondents. Although overall survey results may be presented publicly, respondents should never be publicly identified or associated with their individual responses. The covering letter that was sent to the respondent stated that respondents' information would be treated confidentially.

7.12 Reliability and Validity of the data collection

Bless and Higson-Smith (1995) say that reliability is "concerned with the consistency of measures", thus, the level of reliability in data collection is dependent on its ability to produce the same score when used repeatedly (Babbie and Mouton, 1998). The questionnaire used for the purposes of this study was designed, based on the hypotheses specified above, and each question was linked to an hypothesis to ensure that all hypotheses were captured in the survey questionnaire and the results could be analysed.

According to Babbie, and Mouton (1998) and Bless and Higson-Smith (1995), a questionnaire is valid when it actually measures what it is supposed to measure, given the context in which it is applied. The questionnaire used in this study was examined by an independent expert in consultation with a statistician to ensure that the questionnaire was both valid from a content perspective as well as for conceptual clarity and investigative bias. Furthermore, by targeting specific individuals and organisations, the validity of the findings can be ensured, given that only those who met the criteria participated in the survey.

As mentioned earlier, five people with academic backgrounds originally piloted the online survey. They were not part of the actual study. No major problems were experienced during the pilot study and the data collected was tested to determine the validity and suitability of the statistical process.

7.13 Conclusion

The quantitative research methodology was deemed the most suitable methodology for investigating retailer's perceptions of RFID adoption barriers. A list of hypotheses that were formulated for this exercise were described. A custom survey instrument consisting of 37 questions based on the hypotheses was developed and piloted. The assistance of outside parties such as CGCSA and SACOB proved invaluable in identifying appropriate South African retail companies that could partake in the survey. The Wilcoxon Signed Rank test was chosen as an appropriate statistical tool for Likert scale type data used in the survey. Finally, issues of reliability and validity concerning data collection and analysis for the study were considered and addressed. The detailed results of this survey are reported in the following chapter. For a summarised set of results, please see Appendix C.

Chapter 8

Results

The previous chapter discussed the research methodology. This chapter analyses the data gathered from the questionnaire and interprets the results using statistical methods. A detailed analysis of the hypothesis testing process is provided.

8.1 Introduction

The previous chapter explained the method of data collection and touched on issues pertaining to the actual process of data collection. Once data was collected from the respondents and coded, descriptive statistic methods were performed on the data. The results of the statistical analyses are presented in this chapter, and table 77 reveals a summarised result of the analyses corresponding to individual hypotheses.

8.2 Demographic Profile

Position:	***Frequency***	***Percent***
CEO / CFO / CIO	9	27.3%
President / Vice President	0	0.0%
Managing Director	0	0.0%
Department Manager	11	33.3%
Other Manager	8	24.2%
Senior Staff Members	4	12.1%
Freelancer	0	0.0%
Other	1	3.0%
Total	33	100.0%

Table 20: Position of respondent in the retail organisation

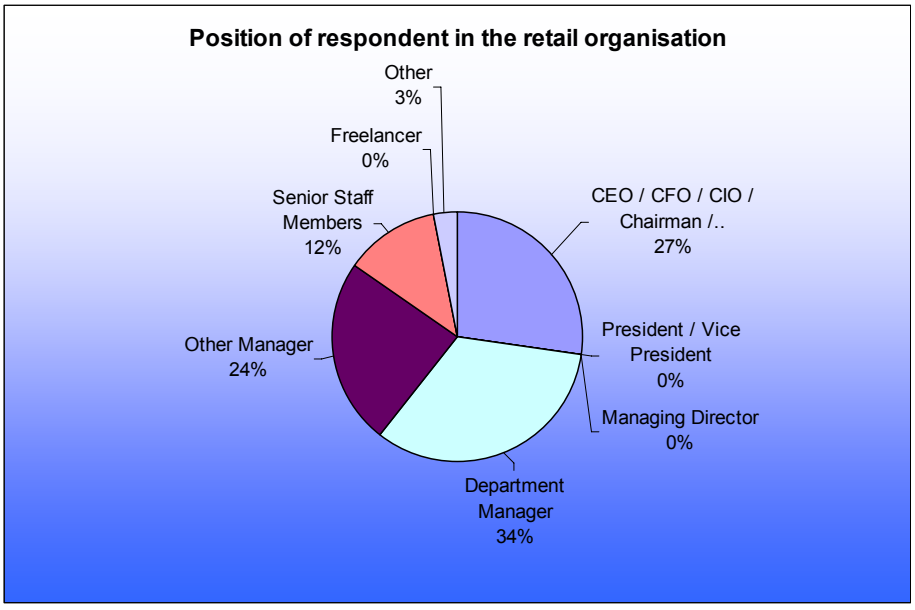

Figure 25: Position of respondent in the retail organisation

The respondents were mostly managers and top executives with Chief Executive Officers (CEO), Chief Financial Officers (CFO) and Chief Information Officers (CIO) constituting 27.3%, Department Managers 33.3% and other mangers 24.2%.

Respondents also include senior staff members 12.1% and other members 3%, which constitute the other 15%. One retailer that outsourced its IT to a professional IT consulting firm; hence, one respondent ('Other') was a senior IT consultant for that particular retailer.

Number of employees in the organisation	*Frequency*	*Percent*
Less than 10	0	0.0%
11 - 50	0	0.0%
51 - 250	6	18.2%
251 - 500	2	6.1%
More than 500	25	75.8%
Total	33	100.0%

Table 21: Number of employees in the retail organisation

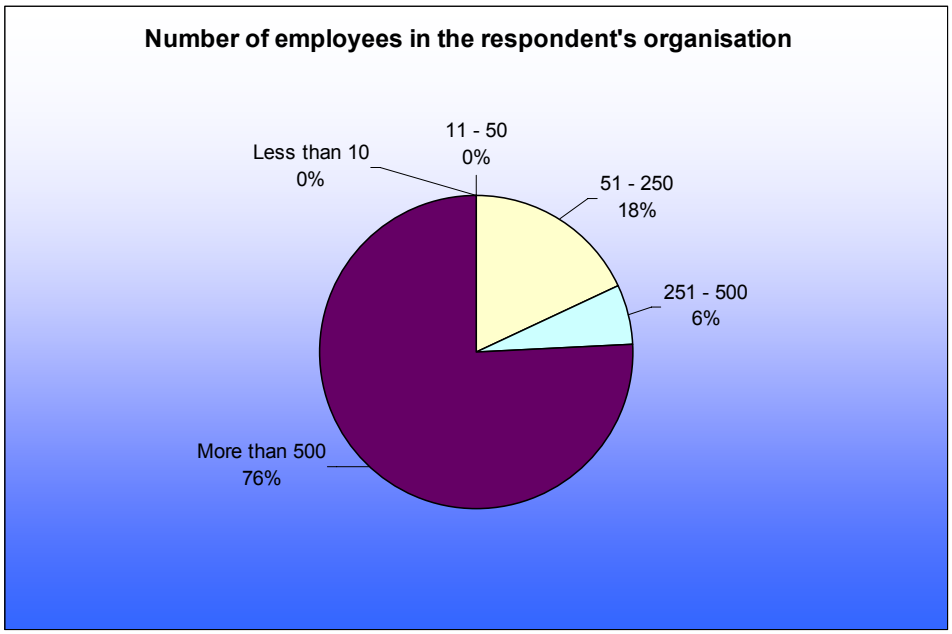

Figure 26: Number of employees in the retail organisation

The size of an organisation can be determined by the number of employees in that organisation. As reflected in Table 21, the majority of organisations surveyed had more than 500 employees (75.8%); the rest, 24.2%, fall under the category of 51-250 employees and 251-500 employees.

8.3 RFID Status in an organisation

Status of RFID adoption in the organisation	*Frequency*	*Percent*
Evaluating the possible use of RFID	17	51.5%
Planning to launch a RFID pilot study	0	0.0%
Planning to implement RFID	0	0.0%
Currently implementing RFID	1	3.0%
RFID already fully implemented	0	0.0%
Not planning to implement RFID	4	12.1%
No RFID-related activities	11	33.3%
Total	33	100.0

Table 22: Status of RFID adoption in the organisation

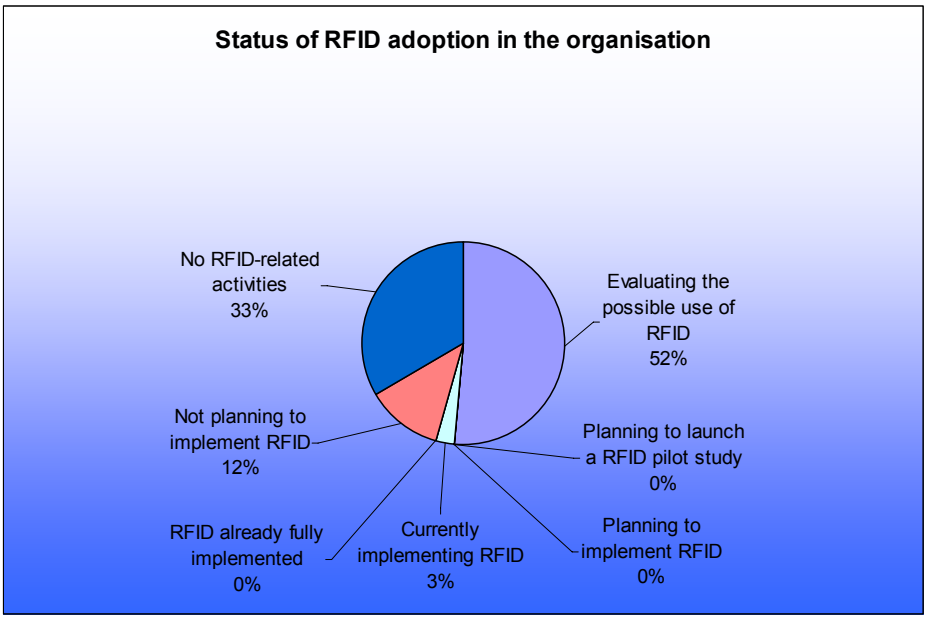

Figure 27: Status of RFID adoption in the organisation

Respondents were asked the status of RFID related activities in their respective retail organisations. 52% of retailers reported they are currently evaluating the possible use of RFID. 33% of respondents reported having no RFID-related activities and 12% said they have no plan to implement RFID technology. This amounts to a total of 45% of respondents who are not currently looking at RFID technology. From these responses, it is clear that it is important to understand the reasons for South African retailers not yet adopting the technology.

Expected implementation of RFID technology	*Frequency*	*Percent*
Immediately	0	0.0%
Within the next twelve months	1	5.9%
One to two years from now	7	41.2%
More than two years from now	8	47.1%
Not relevant	1	5.9%
Total	17	100.0%

Table 23: Expected implementation of RFID technology

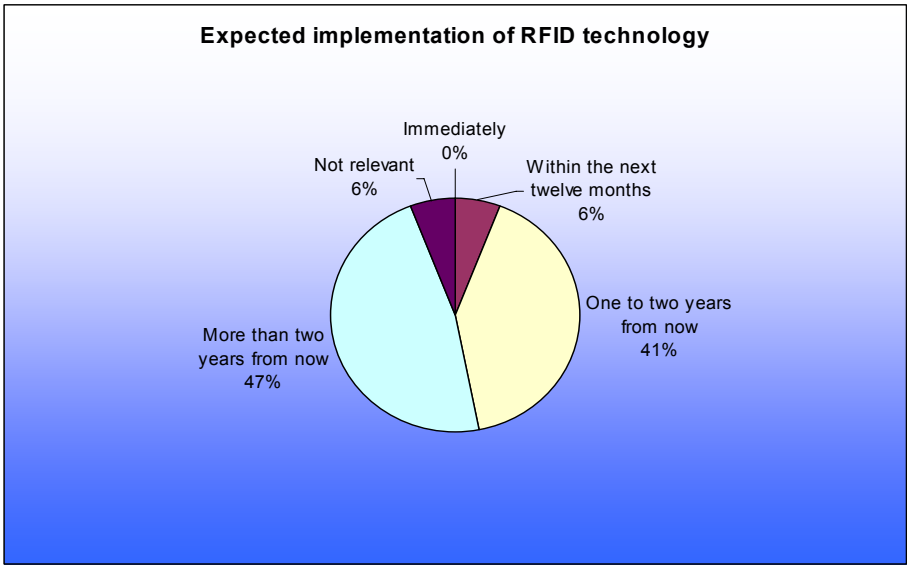

Figure 28: Expected implementation of RFID technology

It is interesting to note that of those retailers who are currently evaluating the possible use of RFID technology, one retailer (6%) is expecting to implement RFID within the next twelve months, and seven retailers (41%) are planning to implement RFID in one to two years from now. Therefore, almost half the respondents who are currently evaluating RFID technology may be expected to implement RFID technology within the next two years. There were, however, eight retailers (47%) expecting to implement RFID technology more than two years from now and one retailer (6%) that is uncertain. Most executives in these retailers are taking a wait-and-see stance, until RFID technology is more matured and cheaper to implement.

8.4 RFID familiarity

Familiarity with RFID technology	*Frequency*	*Percent*
Have never heard of it	0	0.0
May have heard it referred to	5	15.2
Somewhat familiar	2	6.1
Moderately familiar	23	69.7
Extremely Knowledgeable	3	9.1
Total	33	100.0

Table 24: Familiarity with RFID technology

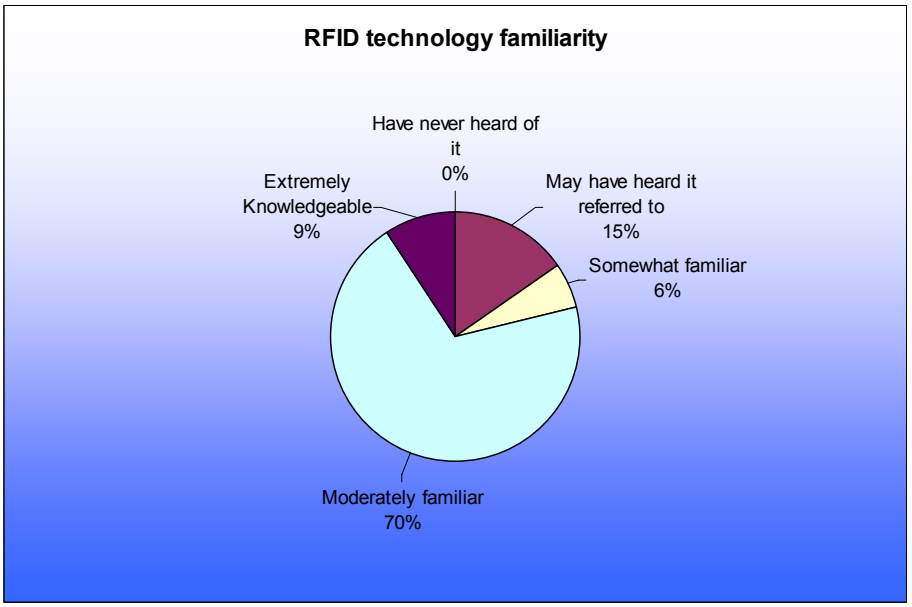

Figure 29: Familiarity with RFID technology

There are 8% of the respondents who are somewhat familiar with RFID technology and 15% that say they may have heard about it. However, the majority of respondents (79%) who participated in the survey are either moderately familiar (70%) with RFID technology or extremely knowledgeable about it (9%). Therefore, most respondents were deemed to have sufficient understanding about RFID technology to answer the survey. It is also interesting to note that most respondents who are familiar with and extremely knowledge about RFID technology are CEOs, CIOs and managers, which indicates that senior management in retail organisations are aware of RFID technology and have adequate understanding about the technology.

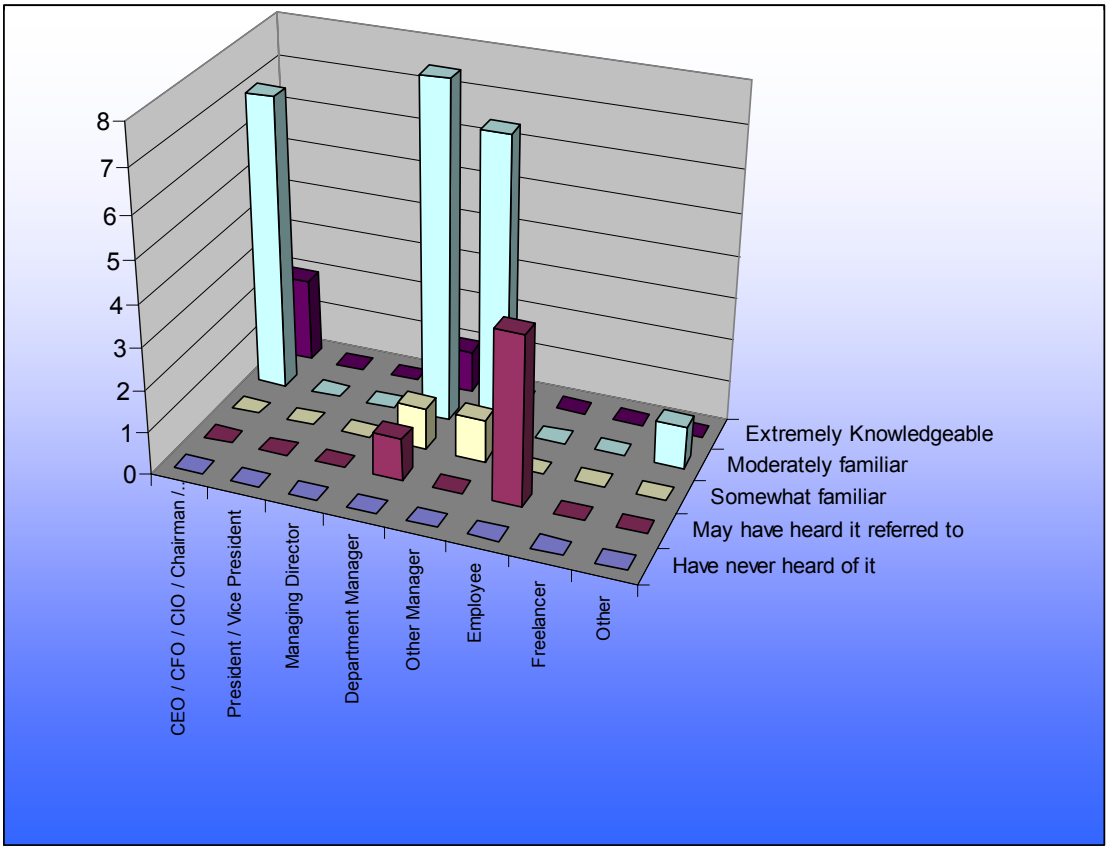

Figure 30: Respondents' position against RFID familiarity

8.5 Questions corresponding with hypotheses

Table 25 shows the corresponding questions formulated based on each hypothesis set.

Categories	Hypotheses Testing	Corresponding Question
Technological	Hypothesis Set 1	Question 8
	Hypothesis Set 2	Question 9
	Hypothesis Set 3	Question 10
	Hypothesis Set 4	Question 11
	Hypothesis Set 5	Question 12 and Question 13
	Hypothesis Set 6	Question 14
	Hypothesis Set 7	Question 15
Cost and ROI	Hypothesis Set 8	Question 16
	Hypothesis Set 9	Question 17
	Hypothesis Set 10	Question 18
	Hypothesis Set 11	Question 19
Privacy and Security	Hypothesis Set 12	Question 20
	Hypothesis Set 13	Question 21
Implementation	Hypothesis Set 14	Question 22
	Hypothesis Set 15	Question 23
	Hypothesis Set 16	Question 24
	Hypothesis Set 17	Question 25
Organisational	Hypothesis Set 18	Question 26
	Hypothesis Set 19	Question 27
	Hypothesis Set 20	Question 28
People	Hypothesis Set 21	Question 29
	Hypothesis Set 22	Question 30
	Hypothesis Set 23	Question 31
Environment	Hypothesis Set 24	Question 32
	Hypothesis Set 25	Question 33

Represent the barriers of RFID adoption in the South African Retail Sector

Table 25: Corresponding questions used for each hypothesis testing

8.6 Statistical Analysis

8.6.1 Hypothesis Set 1: Lack of technological usefulness and advantageousness

H_{01}: Lack of technological usefulness and advantageousness is not a barrier to RFID adoption in the retail sector

H_{11}: Lack of technological usefulness and advantageousness is a barrier to RFID adoption in the retail sector

Question 8: *RFID technology would provide additional value if deployed within the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	0	0.0%
Neutral	6	18.2%
Agree	21	63.6%
Strongly Agree	6	18.2%
Total	33	100.0%

Table 26: RFID technology would provide additional value

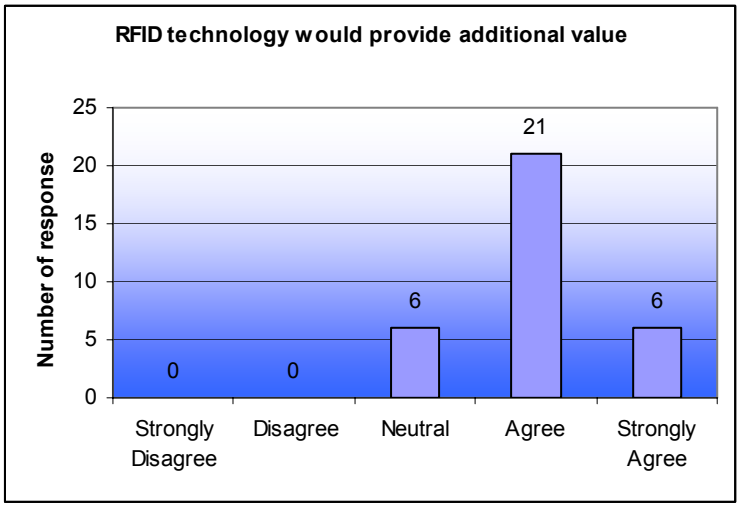

Figure 31: RFID technology would provide additional value

Figure 31 shows that the majority of respondents (63.6%) agree and 18.2% strongly agree, which makes a total of 81.8% of respondents who believe RFID technology would provide additional value if deployed within the retail sector. There are 18.2% of respondents who neither agree nor disagree with this statement, and not a single

respondent believes that RFID would not provide additional value. Hence, RFID technology could be considered useful and could provide additional value if deployed.

Most respondents indicated that they consider RFID technology to be useful and provide addition value if deployed, therefore, lack of technology usefulness and advantageousness seemed not to be a barrier to RFID adoption in the retail sector. To confirm this result, the Wilcoxon Signed Rank test was used, and the following two tests performed on this hypothesis:

	Test 1	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
378	P_1=0.000001	P_2=1

Table 27: Testing RFID technology usefulness and advantageousness when deployed

Test Statement: RFID technology would provide additional value if deployed in the retail sector
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 27 shows the significant difference of Test 1 and Test 2, to be at P_1=0.000001 and P_2=1. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 (P_1=0.000001<0.05), which means the author is highly confident (very small p-value for Test 1) that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement that RFID technology is useful and provides additional value if deployed.

Therefore, there is conclusive evidence that the lack of technological usefulness and advantageousness is not a barrier to RFID adoption in the retail sector, since most respondents perceive RFID technology as useful and believe it will be advantageous to deploy.

8.6.2 Hypothesis Set 2: Lack of a business case

H_{02}: Lack of a business case is not a barrier to RFID adoption in the retail sector

H_{12}: Lack of a business case is a barrier to RFID adoption in the retail sector

Question 9: *There is a convincing business case for RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	4	12.1%
Neutral	9	27.3%
Agree	19	57.6%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 28: Convincing business case for RFID adoption

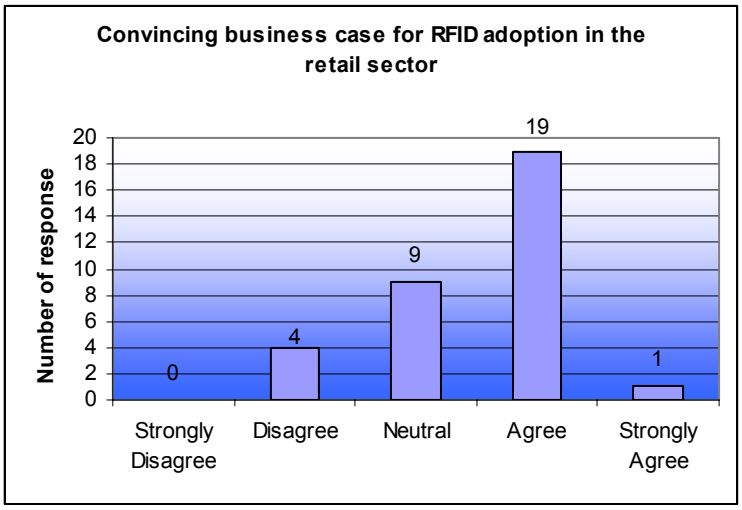

Figure 32: Convincing business case for RFID adoption in the retail sector

Figure 32 shows that the majority of respondents (57.6%) agree and 3% strongly agree, a total of 60.6 percent believe there is a convincing business case for RFID adoption in the retail sector. 27.3% of respondents neither agree nor disagree and 12.1% of respondents disagree with this statement. Therefore, most respondents believe there is a convincing business case for RFID adoption. Therefore, the lack of business case is not a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
252	P_1=0.000566	P_2=0.9995

Table 29: Testing there is a convincing business case for RFID adoption

Test Statement: There is a convincing business case for RFID adoption in the retail sector.

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 29 shows the significant difference of Test 1 and Test 2, to be at P_1=0.000566 and P_2=0.9995. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 (P_1=0.000566<0.05), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement that there is a convincing business case for RFID adoption in the retail sector.

Therefore, there is conclusive evidence that lack of business case is not a barrier to RFID adoption in the retail sector, since most respondents believe there is a convincing business case for RFID adoption.

8.6.3 Hypothesis Set 3: Lack of global standards

H_{03}: Lack of global standards is not a barrier to RFID adoption in the retail sector

H_{13}: Lack of global standards is a barrier to RFID adoption in the retail sector

Question 10: *A lack of RFID global standards is holding back the adoption of RFID technology in retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	2	6.1%
Neutral	9	27.3%
Agree	18	54.5%
Strongly Agree	4	12.1%
Total	33	100.0%

Table 30: Lack of RFID global standards

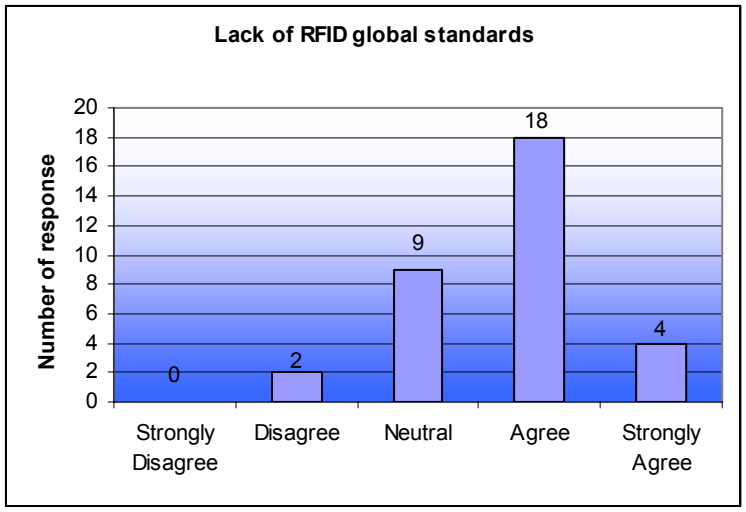

Figure 33: Lack of RFID global standards

Figure 33 shows that the majority of respondents (54.5%) agree and 12.1% strongly agree, which makes a total of 66.6% of respondents who believe that a lack of global standards is a hurdle for RFID adoption. 27.3% of respondents who neither agree nor disagree and 6.1% of respondents disagree with this statement. Therefore, two thirds of respondents believe that a lack of RFID global standards is holding back the adoption of RFID technology in the retail sector.

From the response, most respondents believe a lack of global standards is holding back RFID adoption. Therefore, a lack of global standards is a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
279	$P_1 = 0.00003883$	$P_2 = 1$

Table 31: Testing lack of RFID global standards is holding back RFID adoption

Test Statement: A lack of RFID global standards is holding back the adoption of RFID technology in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 31 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.00003883$ and $P_2=1$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.00003883<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement that a lack of RFID global standards is holding back the adoption of RFID technology in retail sector.

Therefore, there is conclusive evidence that a lack of global RFID standards is a barrier to RFID adoption in the retail sector.

8.6.4 Hypothesis Set 4: Not suitable for product assortment

H_{04}: RFID technology is suitable for product assortment in the retail sector

H_{14}: RFID technology is not suitable for product assortment in the retail sector

Question 11: *RFID technology is suitable for product assortment in the retail sector*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	2	6.1%
Neutral	7	21.1%
Agree	23	69.7%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 32: RFID technology is suitable for product assortment

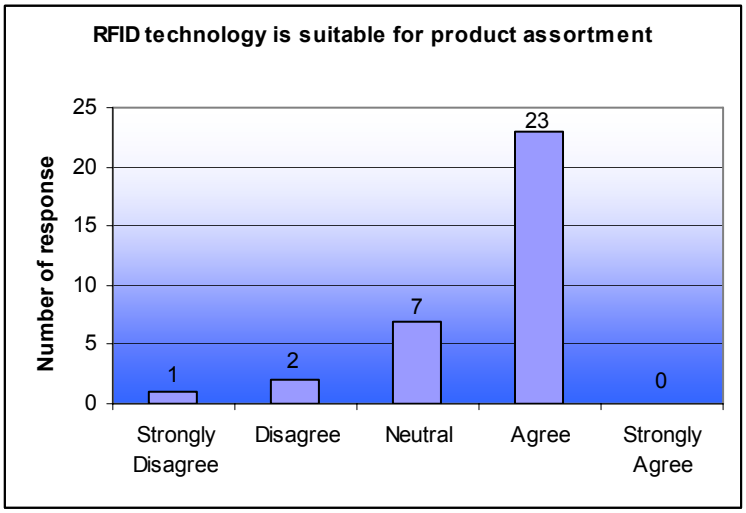

Figure 34: RFID technology is suitable for product assortment

Figure 34 show that the majority of respondents (69.7%) believe RFID technology is suitable for product assortment. There are 21.1% of respondents who neither agree nor disagree, 6.1% of respondents disagree and 3% of respondents strongly disagree with this statement.

From the response, most respondents believe RFID technology is suitable for product assortment in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
299	$P_1 = 0.000221$	$P_2 = 0.9998$

Table 33: Testing RFID technology is suitable for product assortment in the retail sector

Test Statement: RFID technology is suitable for product assortment in the retail sector
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 33 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.000221$ and $P_2=0.9998$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.000221<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement that RFID technology is suitable for product assortment.

Therefore, there is conclusive evidence that RFID technology is suitable for product assortment in the retail sector.

8.6.5 Hypothesis Set 5: Poor tag reader accuracy and read rate

H_{05}: Poor tag reader accuracy and read rate is not a barrier to RFID adoption in the retail sector

H_{15}: Poor tag reader accuracy and read rate is a barrier to RFID adoption in the retail sector

Question 12: *Poor reader accuracy is a barrier to RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	6	18.2%
Neutral	14	42.4%
Agree	11	33.3%
Strongly Agree	2	6.1%
Total	33	100.0%

Table 34: Poor RFID reader accuracy

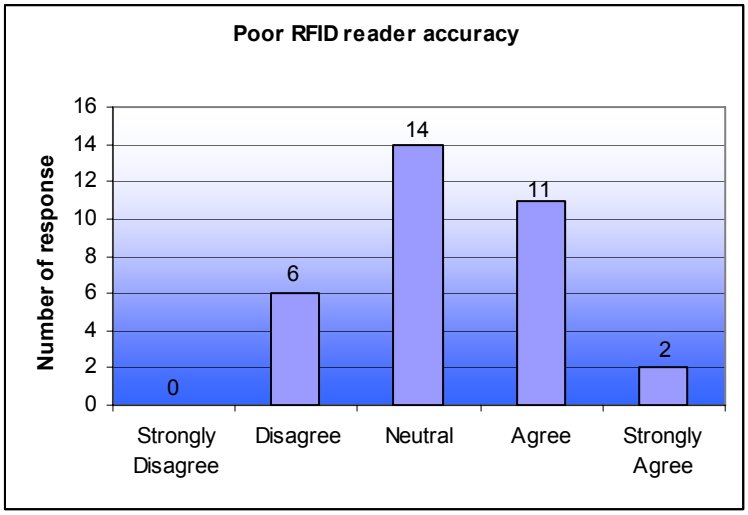

Figure 35: Poor RFID reader accuracy

Figure 35 shows that 42.4% of respondents neither agree nor disagree with this question. However, 33.3% of respondents agree and 6.1% strongly agree that poor reader accuracy is a barrier to RFID adoption. Furthermore, 18.2% of respondents disagree with this statement.

Question 13: *Poor read rate is a barrier to RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	4	12.1%
Neutral	18	54.5%
Agree	9	27.3%
Strongly Agree	2	6.1%
Total	33	100.0%

Table 35: Poor RFID read rate

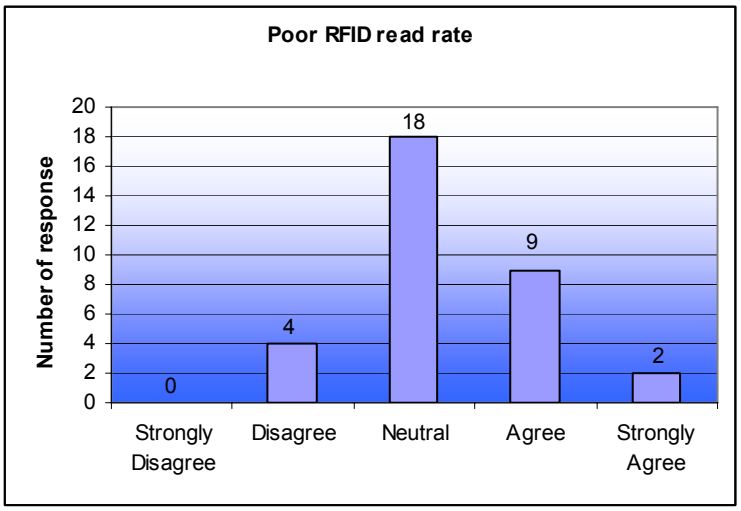

Figure 36: Poor RFID read rate

Figure 36 shows that 54.5% of respondents neither agree nor disagree. However, 27.3% of respondents agree and 6.1% strongly agree that poor RFID read rate is a barrier to RFID adoption. Furthermore, 12.1% of respondents disagree with this statement.

Given the response from question 12 and 13, there is no convincing result as to whether or not poor RFID reader accuracy and read rate is or is not a barrier to adoption, however, more respondents agree with this statement than those that disagree. Therefore, The Wilcoxon Signed Rank test was used to analyse this result and the following four tests are performed on this hypothesis:

	Test Poor RFID reader accuracy	
	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
136	P_1= 0.03721	P_2=0.9662

	Test Poor RFID read rate	
	Test 3:	**Test 4**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
92	P_1= 0.02635	P_2=0.9772

Table 36: Testing Poor RFID reader accuracy and read rate

Test Statement: Poor reader accuracy and read rate is a barrier to RFID adoption in the retail sector.

Test 1 & 3: determines if the response is neutral or agrees with the statement.

Test 2 & 4: determines if the response is neutral or disagrees with the statement.

Table 36 shows the significant difference of Test 1, Test 2, Test 3 and Test 4, to be at P_1=0.03721, P_2=0.9662, P_1=0.02635 and P_2=0.9772. Thus the author fails to reject the null hypothesis for both Test 2 and Test 4, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2 and Test 4. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 and Test 3 (P_1=0.03721<0.05, P_1=0.02635<0.05), which means the author is confident that the alternative hypothesis, H_1 for Test 1 and Test 3 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement that poor reader accuracy and read rate is a barrier.

Therefore, there is conclusive evidence that poor tag reader accuracy and read rate is a barrier to RFID adoption in the retail sector

8.6.6 Hypothesis Set 6: Large amount of data would swamp the business

H_{06}: Data overflow generated by RFID technology is not a barrier to RFID adoption in the retail sector

H_{16}: Data overflow generated by RFID technology is a barrier to RFID adoption in the retail sector

Question 14: *RFID systems will generate too much data that will become difficult to manage*

	Count	*Percent*
Strongly Disagree	4	12.1%
Disagree	20	60.6%
Neutral	7	21.2%
Agree	1	3.0%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 37: RFID systems generates too much data

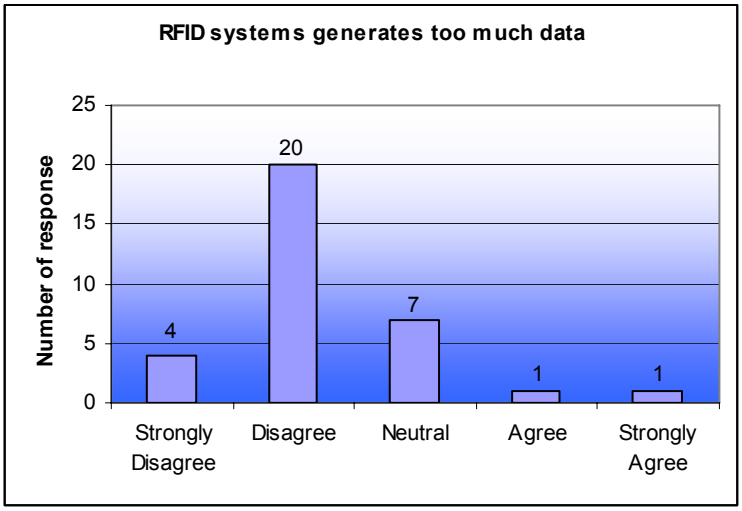

Figure 37: RFID systems generates too much data

Figure 37 shows that the majority of respondents (60.6%) disagree and 12.1% strongly disagree, which makes a total of 72.7% of respondents who believe an RFID system does not generate too much data. There are 21.2% of respondents who neither agree nor disagree and 6% of respondents agree and strongly agree with this statement.

From the response, most respondents believe that RFID systems will not generate too much data that will become difficult to manage. The Wilcoxon Signed Rank test was

used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
35	$P_1 = 1$	$P_2 = 0.0000715$

Table 38: Testing RFID systems will generate too much data that will become difficult to manage

Test Statement: RFID systems will generate too much data that will become difficult to manage

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 38 shows the significant difference of Test 1 and Test 2, to be at $P_1=1$ and $P_2=0.0000715$. Thus the author fails to reject the null hypothesis for Test 1, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 2 ($P_2=0.0000715<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 2 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response disagrees with the statement. This means RFID systems will not generate too much data that will become difficult to manage.

Therefore, there is conclusive evidence that data overflow generated by RFID technology is not a barrier to RFID adoption in the retail sector

8.6.7 Hypothesis Set 7: Complexity of technology

H_{07}: Complexity of technology is not a barrier to RFID adoption in the retail sector

H_{17}: Complexity of technology is a barrier to RFID adoption in the retail sector

Question 15: *RFID systems are too complex for users, such as employees and consumers*

	Count	*Percent*
Strongly Disagree	7	21.2%
Disagree	18	54.5%
Neutral	6	18.2%
Agree	2	6.1%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 39: RFID systems generates too much data

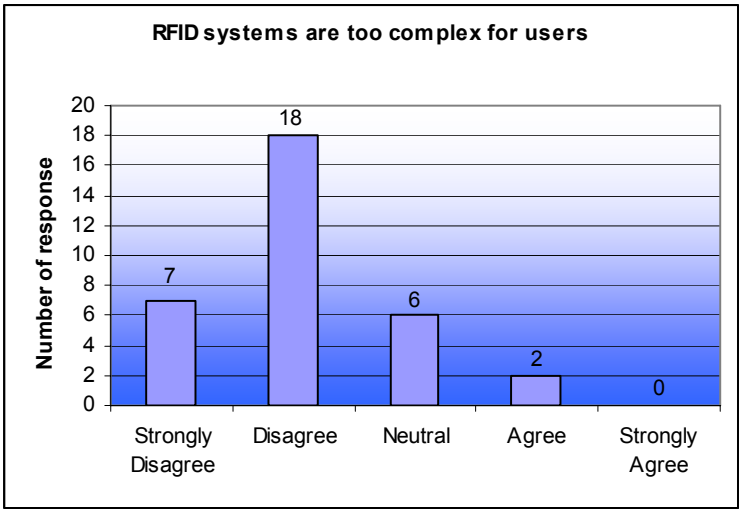

Figure 38: RFID systems are too complex for users

Figure 38 indicates that the majority of respondents (54.5%) disagree and 21.2% strongly disagree, which makes a total of 75.7% of respondents who believe RFID systems are not too complex for users. 18.2% of respondents neither agree nor disagree and 6.1% of respondents agree with this statement.

From the response, most respondents believe that RFID systems are not too complex for users, such as employees and consumers. The Wilcoxon Signed Rank test was

used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
21	$P_1 = 1$	$P_2 = 0.0000111$

Table 40: Testing RFID systems are too complex for users, such as employees and consumers

Test Statement: RFID systems are too complex for users, such as employees and consumers

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 40 shows the significant difference of Test 1 and Test 2, to be at $P_1=1$ and $P_2=0.0000111$. Thus the author fails to reject the null hypothesis for Test 1, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 2 ($0.0000111<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 2 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response disagrees with the statement. This means RFID systems are not too complex for users, such as employees and consumers.

Therefore, there is conclusive evidence that Complexity of technology is not a barrier to RFID adoption in the retail sector.

8.6.8 Hypothesis Set 8: The high cost of hardware and infrastructure

H_{08}: The high cost of hardware and infrastructure is not a barrier for RFID adoption in the retail sector

H_{18}: The high cost of hardware and infrastructure is a barrier for RFID adoption in the retail sector

Question 16: *The high cost of RFID hardware and infrastructure is a barrier to the adoption of RFID in the retail sector*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	2	6.1%
Neutral	5	15.2%
Agree	18	54.5%
Strongly Agree	7	21.2%
Total	33	100.0%

Table 41: The high cost of RFID hardware and infrastructure is a barrier

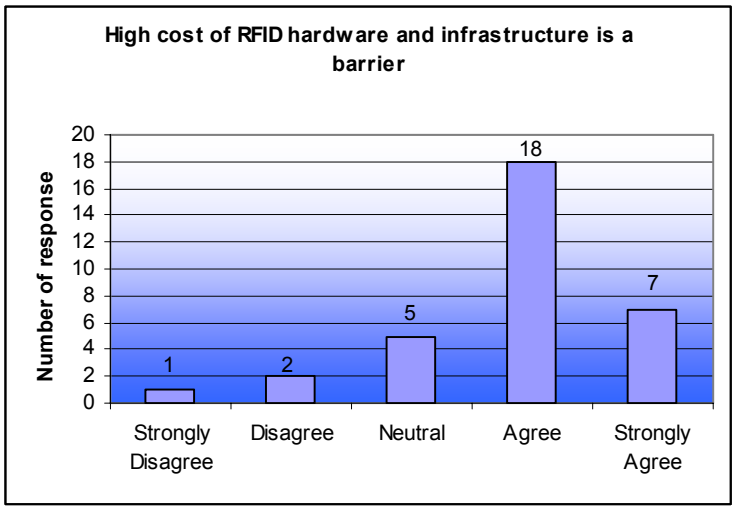

Figure 39: The high cost of RFID hardware and infrastructure is a barrier

Figure 39 indicates that the majority of respondents (54.5%) agree and 21.2% strongly agree, which makes a total of 75.7% of respondents who believe the high cost of RFID hardware and infrastructure is a barrier. 15.2% of respondents neither agree nor disagree, 6.1% of respondents disagree and 3% of respondents strongly disagree with this statement.

From the response, most respondents believe that the high cost of RFID hardware and infrastructure is a barrier for RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
360.5	$P_1 = 0.000088$	$P_2 = 1$

Table 42: Testing the high cost of RFID hardware and infrastructure is a barrier to the adoption of RFID in the retail sector

Test Statement: The high cost of RFID hardware and infrastructure is a barrier to the adoption of RFID in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 42 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.000088$ and $P_2=1$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.000088<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement. This means the high cost of RFID hardware and infrastructure is a barrier.

Therefore, there is conclusive evidence that the high cost of hardware and infrastructure is a barrier for RFID adoption in the retail sector.

8.6.9 Hypothesis Set 9: The high cost of software, integration, service, and support

H_{09}: The high cost of software, integration, service, and support is not a barrier for RFID adoption in the retail sector

H_{19}: The high cost of software, integration, service, and support is a barrier for RFID adoption in the retail sector

Question 17: *The high cost of RFID software, integration, service, and support is a barrier to the adoption of RFID in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	1	3.0%
Neutral	8	24.2%
Agree	17	51.5%
Strongly Agree	7	21.2%
Total	33	100.0%

Table 43: The high cost of RFID software, integration, service and support is a barrier

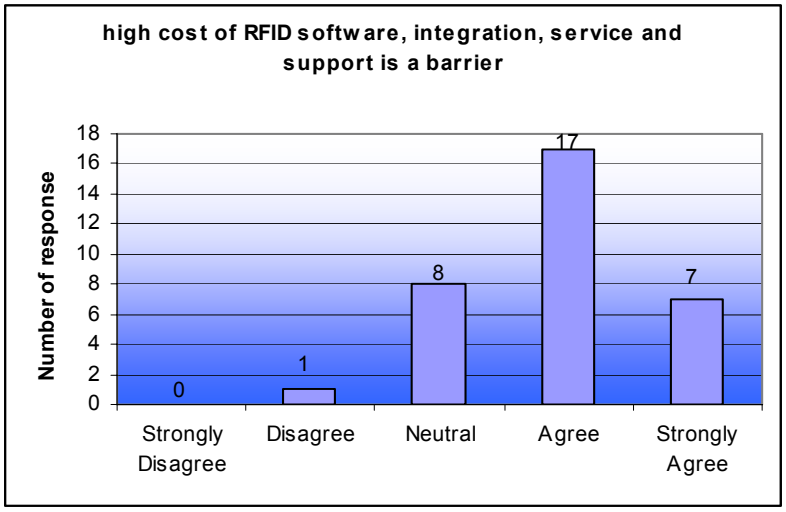

Figure 40: The high cost of RFID software, integration, service and support is a barrier

Figure 40 indicates that the majority of respondents (51.5%) agree and 21.2% strongly agree, which makes a total of 72.7% of respondents who believe the high cost of RFID software, integration, service and support is a barrier. 24.2% of respondents who neither agree nor disagree and 3% of respondents who disagree with this statement.

From the response, most respondents believe that the high cost of RFID software, integration, service and support is a barrier for RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
315.5	$P_1 = 0.000008$	$P_2 = 1$

Table 44: Testing the high cost of RFID software, integration, service and support is a barrier to the adoption of RFID in the retail sector

Test Statement: The high cost of RFID software, integration, service and support is a barrier to the adoption of RFID in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 44 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.000008$ and $P_2=1$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.0000008<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement. This means the high cost of RFID software, integration, service and support is a barrier.

Therefore, there is conclusive evidence that the high cost of software, integration, service and support is a barrier for RFID adoption in the retail sector.

8.6.10 Hypothesis Set 10: The high cost of tags

H_{010}: The high cost of tags is not a barrier to RFID adoption in the retail sector

H_{110}: The high cost of tags is a barrier to RFID adoption in the retail sector

Question 18: *The high cost of RFID tags is a reason causing retailers to hold back on the adoption of RFID technology*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	3	9.1%
Neutral	6	18.2%
Agree	7	21.2%
Strongly Agree	17	51.5%
Total	33	100.0%

Table 45: The high cost of RFID tags is a barrier

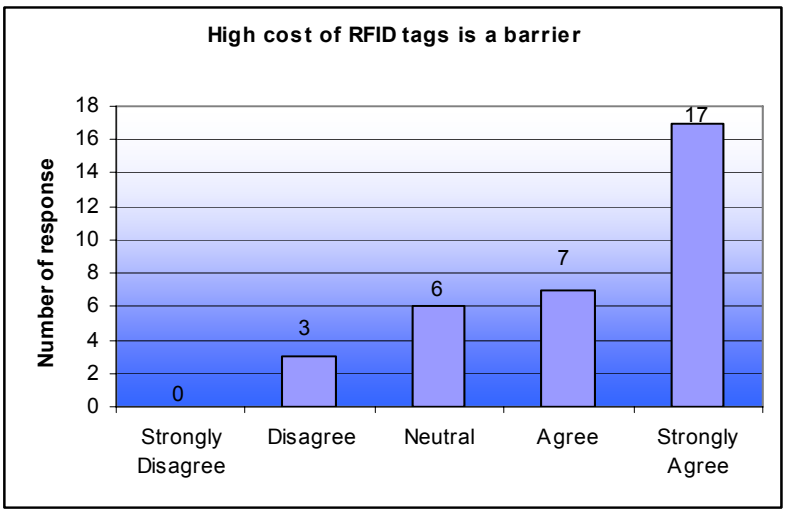

Figure 41: The high cost of RFID tags is a barrier

Figure 41 indicates that the majority of respondents (51.5%) strongly agree and 21.2% agree, which makes a total of 72.7% of respondents who believe the high cost of RFID tags is a barrier. There are 18.2% of respondents who neither agree nor disagree and 9.1% of respondents disagree with this statement.

From the response, most respondents believe that the high cost of RFID tags is a barrier for RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
361.5	P_1= 0.000009	P_2=1

Table 46: Testing the high cost of RFID tags is a barrier to the adoption of RFID in the retail sector

Test Statement: The high cost of RFID tags is a barrier to the adoption of RFID in the retail sector.

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 46 shows the significant difference of Test 1 and Test 2, to be at P_1=0.000009 and P_2=1. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 (P_1=0.0000009<0.05), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement. This means the high cost of RFID tags is a barrier.

Therefore, there is conclusive evidence that the high cost of tags is a barrier for RFID adoption in the retail sector.

8.6.11 Hypothesis Set 11: Unclear ROI

H_{011}: Unclear ROI is not a barrier for RFID adoption in the retail sector

H_{111}: Unclear ROI is a barrier for RFID adoption in the retail sector

Question 19: *Uncertainty in return on investment for an RFID system is an obstacle in the adoption of RFID technology*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	5	15.2%
Neutral	5	15.2%
Agree	17	51.5%
Strongly Agree	6	18.2%
Total	33	100.0%

Table 47: Uncertainty in return on investment (ROI)

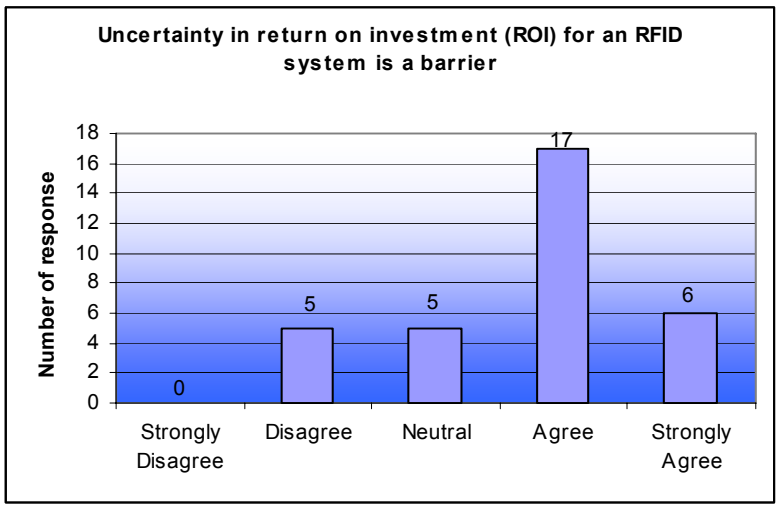

Figure 42: Uncertainty in return on investment (ROI)

Figure 42 indicates that the majority of respondents (51.5%) agree and 18.2% strongly agree, which makes a total of 69.7% of respondents who believe uncertainty in return on investment is a barrier. 15.2% of respondents neither agree nor disagree and 15.2% of respondents disagree with this statement.

From the response, most respondents believe that uncertainty in return on investment (ROI) is a barrier for RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
348.5	$P_1 = 0.000221$	$P_2 = 0.9998$

Table 48: Testing uncertainty in return on investment (ROI) is an obstacle in the adoption of RFID technology

Test Statement: Uncertainty in return on investment (ROI) is an obstacle in the adoption of RFID technology

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 48 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.000221$ and $P_2=0.9998$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.000221<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response corresponds with the statement. This means uncertainty in return on investment (ROI) is an obstacle.

Therefore, there is conclusive evidence that unclear ROI is a barrier for RFID adoption in the retail sector.

8.6.12 Hypothesis Set 12: Customer privacy concerns

H_{012}: Customer privacy concerns are not a barrier to RFID adoption in the retail sector

H_{112}: Customer privacy concerns are a barrier to RFID adoption in the retail sector

Question 20: *The impact of consumer privacy is a concern for RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	12	36.4%
Neutral	8	24.2%
Agree	12	36.4%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 49: Impact of consumer privacy is a concern

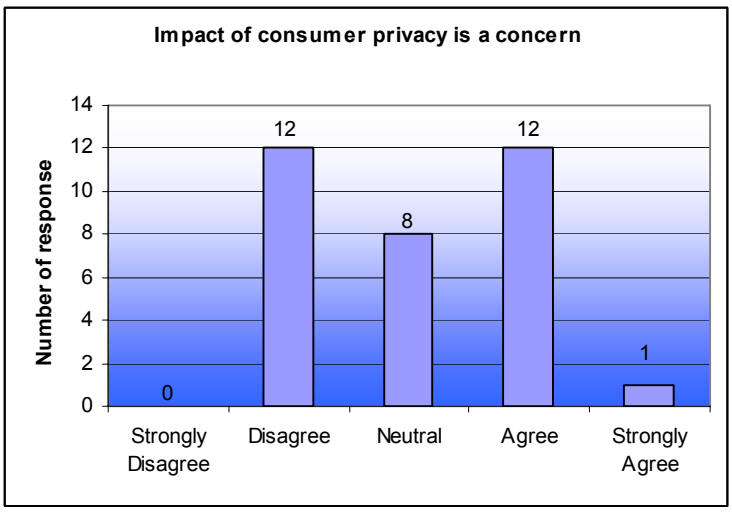

Figure 43: Impact of consumer privacy is a concern

Figure 43 indicates that 36.4% agree and 3% strongly agree, which makes a total of 39.4% of respondents who believe consumer privacy is a concern. However, there are 36.4% of respondents who disagree with this statement, and 24.2% neither agree nor disagree.

From the response, there is no evidence to indicate whether or not the impact of consumer privacy is a concern for RFID adoption in the retail sector, since the number

of responses is distributed evenly amongst disagree and agree. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
175	$P_1 = 0.3584$	$P_2 = 0.6529$

Table 50: Testing the impact of consumer privacy is a concern for RFID adoption in the retail sector

Test Statement: The impact of consumer privacy is a concern for RFID adoption in the retail sector

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 50 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.3584$ and $P_2=0.6529$. Thus the author fails to reject the null hypothesis for both Test 1 and Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1 and Test 2. As a result, the response is not significantly different to neutral. Hence, the final conclusion from the statistical result shows the response neither agrees nor disagrees with the statement.

Therefore, there is no conclusive evidence indicating that the impact of consumer privacy concern is or is not a barrier to RFID adoption in the retail sector.

8.6.13 Hypothesis Set 13: Security concerns

H_{013}: Security concerns are not a barrier to RFID adoption in the retail sector

H_{113}: Security concerns are a barrier to RFID adoption in the retail sector

Question 21: *RFID security is a concern in the adoption of RFID technology*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	10	30.3%
Neutral	13	39.4%
Agree	9	27.3%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 51: RFID security is a concern

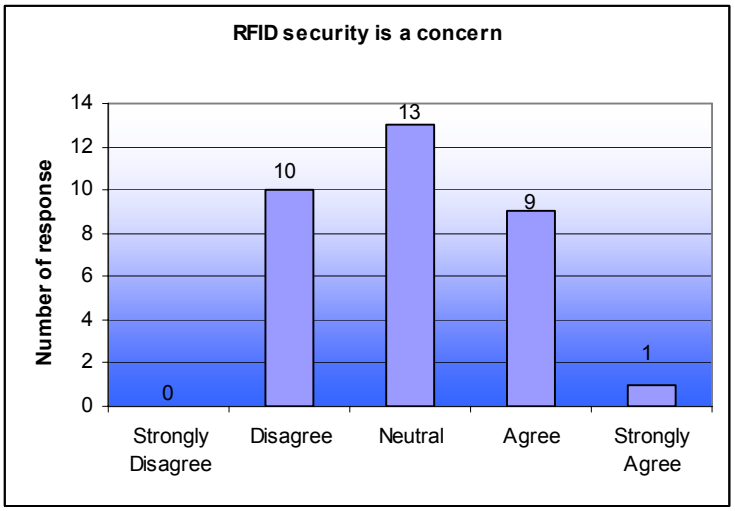

Figure 44: RFID security is a concern

Figure 44 indicates that 27.3% agree and 3% strongly agree, which makes a total of 30.3% of respondents who believe RFID security is a concern. However, there are 30.3% of respondents who disagree with this statement, and 39.4% neither agree nor disagree.

From the response, there is no evidence to indicate whether or not RFID security is a concern for RFID adoption in the retail sector, since the number of responses are distributed evenly amongst disagree and agree. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
110	P_1= 0.4256	P_2=0.5907

Table 52: Testing RFID security is a concern in the adoption of RFID technology

Test Statement: RFID security is a concern in the adoption of RFID technology

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 52 shows the significant difference of Test 1 and Test 2, to be at P_1=0.4256 and P_2=0.5907. Thus the author fails to reject the null hypothesis for both Test 1 and Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1 and Test 2. As a result, the response is not significantly different to neutral. Hence, the final conclusion from the statistical result shows the response neither agrees nor disagrees with the statement.

Therefore, there is no conclusive evidence indicating that the security concern is or is not a barrier to RFID adoption in the retail sector.

8.6.14 Hypothesis Set 14: Compatibility and integration with other technology

H_{014}: Compatibility and integration of RFID with other technology is not a barrier to RFID adoption in the retail sector

H_{114}: Compatibility and integration of RFID with other technology is a barrier to RFID adoption in the retail sector

Question 22: *Difficulties in compatibility and integration of RFID with other technology are a barrier to RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	6	18.2%
Neutral	12	36.4%
Agree	13	39.4%
Strongly Agree	2	6.1%
Total	33	100.0%

Table 53: Difficulties in compatibility and integration of RFID with other technology are a barrier

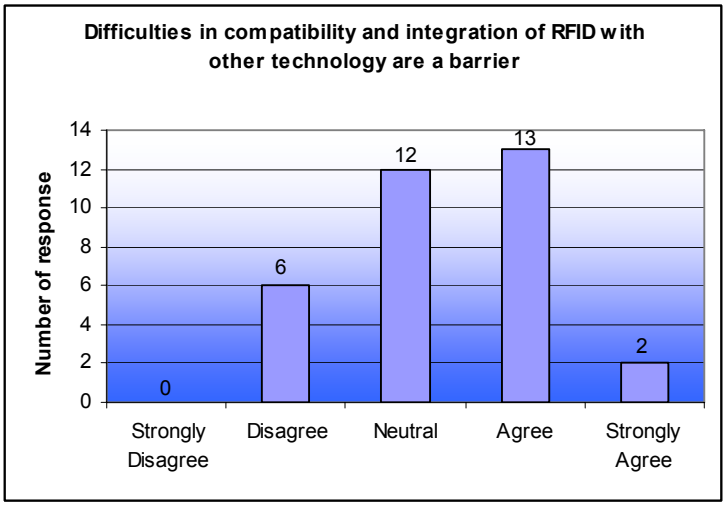

Figure 45: Difficulties in compatibility and integration of RFID with other technology are a barrier

Figure 45 indicates that the majority of respondents (39.4%) agree and 6.1% strongly agree, which makes a total of 45.5% of respondents who believe that difficulties in compatibility and integration of RFID with other technology are a barrier. There are 36.4% of respondents who neither agree nor disagree and 18.2% of respondents disagree with this statement.

From the response, most respondents believe that compatibility and integration of RFID with other technology is a barrier. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
171	$P_1 = 0.01781$	$P_2 = 0.9838$

Table 54: Testing Difficulties in compatibility and integration of RFID with other technology are a barrier

Test Statement: Difficulties in compatibility and integration of RFID with other technology are a barrier to RFID adoption in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 54 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.01781$ and $P_2=0.9838$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.01781<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence that compatibility and integration of RFID with other technology is a barrier to RFID adoption in the retail sector.

8.6.15 Hypothesis Set 15: Implementation Challenges

H_{015}: Implementation Challenges are not a barrier to RFID adoption in the retail sector

H_{115}: Implementation Challenges are a barrier to RFID adoption in the retail sector

Question 23: *Challenges relating to RFID implementation are a stumbling block in the adoption of RFID technology*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	3	9.1%
Neutral	7	21.2%
Agree	22	66.7%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 55: Challenges relating to RFID implementation is a barrier

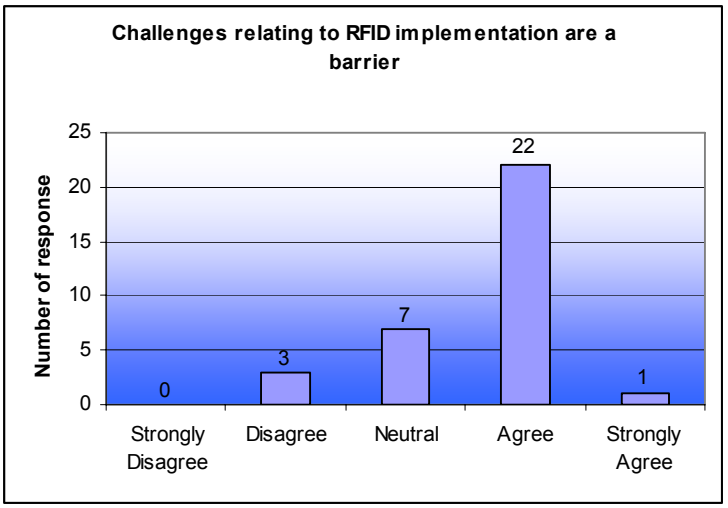

Figure 46: Challenges relating to RFID implementation is a barrier

Figure 46 indicates that the majority of respondents (66.7%) agree and 3% strongly agree, which makes a total of 69.7% of respondents who believe that challenges relating to RFID implementation are a barrier. There are 21.2% of respondents who neither agree nor disagree and 9.1% of respondents disagree with this statement.

From the response, most respondents believe that implementation challenges are a barrier. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
312	$P_1 = 0.000051$	$P_2 = 1$

Table 56: Testing challenges relating to RFID implementation are a stumbling block in the adoption of RFID technology

Test Statement: Challenges relating to RFID implementation are a stumbling block in the adoption of RFID technology

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 56 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.000051$ and $P_2=1$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.000051<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence that implementation challenges are a barrier to RFID adoption in the retail sector.

8.6.16 Hypothesis Set 16: The need to address data synchronisation first

H_{016}: The need to address data synchronisation is not a barrier to RFID adoption in the retail sector

H_{116}: The need to address data synchronisation is a barrier to RFID adoption in the retail sector

Question 24: *Data synchronisation between RFID systems and other systems is a problem in RFID adoption*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	17	51.5%
Neutral	7	21.2%
Agree	8	24.2%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 57: Data synchronisation between RFID systems and other systems

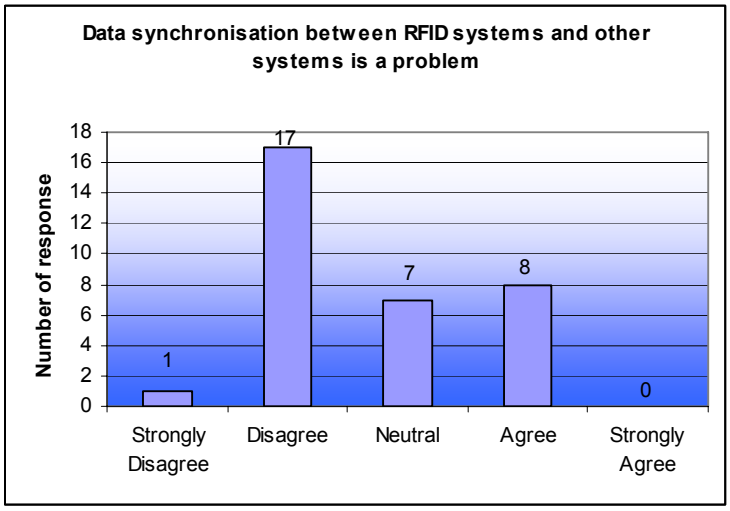

Figure 47: Data synchronisation between RFID systems and other systems

Figure 47 indicates that the majority of respondents (51.5%) disagree and 3% strongly disagree, which makes a total of 54.5% of respondents who believe that data synchronisation between RFID systems and other systems is a problem. There are 21.2% of respondents who neither agree nor disagree and 24.2% of respondents agree with this statement.

From the response, most respondents believe the need to address data synchronisation is not a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
104	$P_1 = 0.9802$	$P_2 = 0.02126$

Table 58: Testing data synchronisation between RFID systems and other systems is a problem in RFID adoption

Test Statement: Data synchronisation between RFID systems and other systems is a problem in RFID adoption

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 58 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.9802$ and $P_2=0.02126$. Thus the author fails to reject the null hypothesis for Test 1, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 2 ($P_2=0.02126<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 2 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response disagrees with the statement that data synchronisation between RFID systems and other systems is not a problem in RFID adoption

Therefore, there is conclusive evidence that the need to address data synchronisation is not a barrier to RFID adoption in the retail sector since most respondents perceive data synchronisation between RFID systems and other systems to not be a problem.

8.6.17 Hypothesis Set 17: RFID authentication challenges

H_{017}: RFID authentication challenges are not a barrier to RFID adoption in the retail sector

H_{117}: RFID authentication challenges are a barrier to RFID adoption in the retail sector

Question 25: *A lack of authentication in RFID systems and tags is a barrier to RFID technology adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	6	18.2%
Neutral	22	66.7%
Agree	5	15.2%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 59: Lack of authentication in RFID systems and tags is a barrier

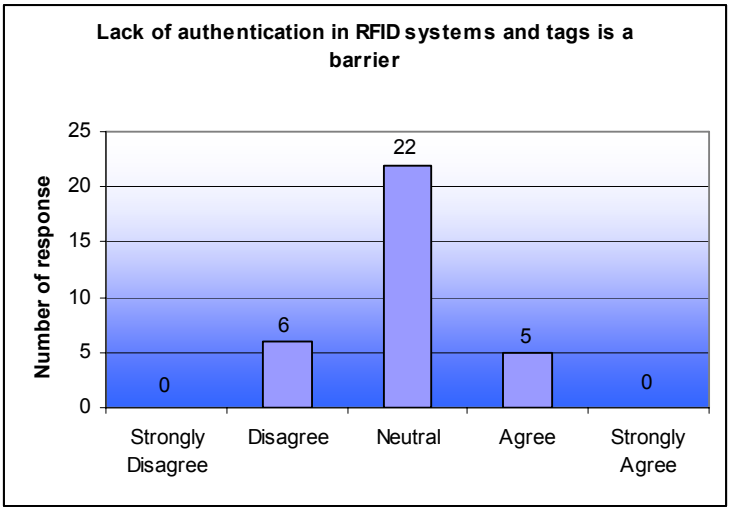

Figure 48: Lack of authentication in RFID systems and tags is a barrier

Figure 48 indicates that 15.2% of respondents agree, 66.7% neither agree nor disagree and 18.2% disagree that a lack of authentication in RFID systems and tags is an adoption barrier.

From the response, there is no evidence indicating whether or not RFID authentication challenges are a barrier to RFID adoption in the retail sector, since the number of responses are distributed evenly amongst disagree and agree, and the majority

answered neutral. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
30	$P_1 = 0.6375$	$P_2 = 0.4008$

Table 60: Testing lack of authentication in RFID systems and tags is a barrier to RFID technology adoption

Test Statement: A lack of authentication in RFID systems and tags is a barrier to RFID technology adoption

Test 1: determines if the response is neutral or agrees with the statement.

Test 2: determines if the response is neutral or disagrees with the statement.

Table 60 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.6375$ and $P_2=0.4008$. Thus the author fails to reject the null hypothesis for both Test 1 and Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1 and Test 2. As a result, the response is not significantly different to neutral. Hence, the final conclusion from the statistical result shows the response neither agrees nor disagrees with the statement.

Therefore, there is no conclusive evidence indicating that a RFID authentication challenge is or is not a barrier to RFID adoption in the retail sector.

8.6.18 Hypothesis Set 18: A high degree of business process change required

H_{018}: A high degree of business process change is not a barrier to RFID adoption in the retail sector

H_{118}: A high degree of business process change is a barrier to RFID adoption in the retail sector

Question 26: *The high degree of business process change required for RFID adoption is an obstacle in the retail sector*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	7	21.2%
Neutral	6	18.2%
Agree	18	54.5%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 61: High degree of business process change required for RFID adoption is a barrier

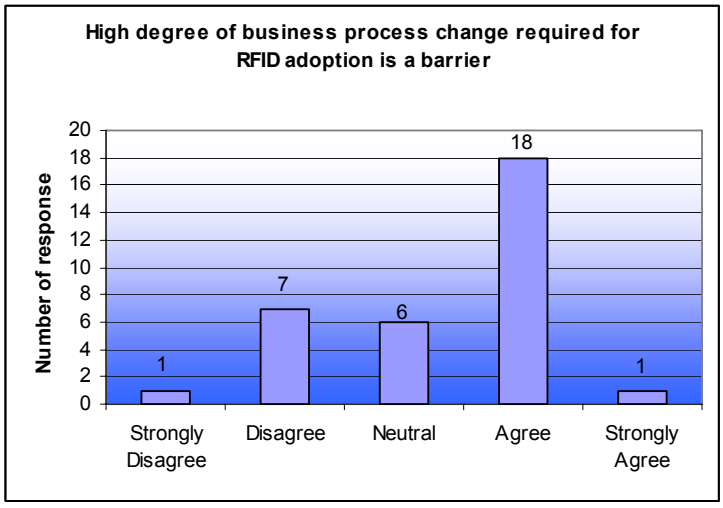

Figure 49: High degree of business process change required for RFID adoption is a barrier

Figure 49 indicates that the majority of respondents (54.5%) agree and 3% strongly agree, which makes a total of 57.5% of respondents who believe that a high degree of business process change required is a barrier. There are 18.2% of respondents who neither agree nor disagree, 21.2% of respondents disagree and 3% of respondents strongly disagree with this statement.

From the response, most respondents believe that a high degree of business change is a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
260.5	$P_1 = 0.02921$	$P_2 = 0.9725$

Table 62: Testing the high degree of business process change required for RFID adoption is an obstacle in the retail sector

Test Statement: The high degree of business process change required for RFID adoption is an obstacle in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 62 shows the significant difference of Test 1 and Test 2, to be at P_1=0. 02921 and P_2=0.9725. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 (P_1=0.02921<0.05), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence to suggest that a high degree of business change is a barrier to RFID adoption in the retail sector.

8.6.19 Hypothesis Set 19: Lack of awareness

H_{019}: Lack of awareness is not a barrier to RFID adoption in the retail sector

H_{119}: Lack of awareness is a barrier to RFID adoption in the retail sector

Question 27: *A lack of awareness in RFID technology is holding back the adoption of RFID in the retail sector*

	Count	*Percent*
Strongly Disagree	2	6.1%
Disagree	7	21.2%
Neutral	4	12.1%
Agree	16	48.5%
Strongly Agree	4	12.1%
Total	33	100.0%

Table 63: Lack of awareness in RFID technology

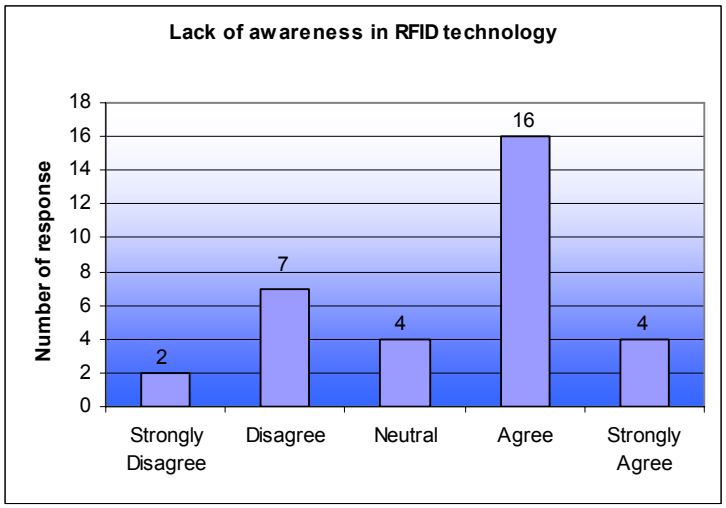

Figure 50: Lack of awareness in RFID technology

Figure 50 indicates that the majority of respondents (48.5%) agree and 12.1% strongly agree, which makes a total of 60.6% of respondents who believe that a lack of awareness in RFID technology is a barrier. There are 12.1% of respondents who neither agree nor disagree, 21.2% of respondents disagree and 6.1% of respondents strongly disagree with this statement.

From the response, most respondents believe that a lack of awareness is a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
298	$P_1 = 0.03256$	$P_2 = 0.969$

Table 64: Testing lack of awareness in RFID technology is holding back the adoption of RFID

Test Statement: A lack of awareness in RFID technology is holding back the adoption of RFID in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 64 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.03256$ and $P_2=0.969$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.03256<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence that lack of awareness is a barrier to RFID adoption in the retail sector.

8.6.20 Hypothesis Set 20: A lack of identifiable business needs

H_{020}: A lack of identifiable business needs is not a barrier to RFID adoption in the retail sector

H_{120}: A lack of identifiable business needs is a barrier to RFID adoption in the retail sector

Question 28: *A lack of identifiable business needs for RFID technology in the retail sector is a factor holding back RFID adoption*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	15	45.5%
Neutral	5	15.2%
Agree	10	30.3%
Strongly Agree	2	6.1%
Total	33	100.0%

Table 65: A lack of identifiable business needs for RFID technology

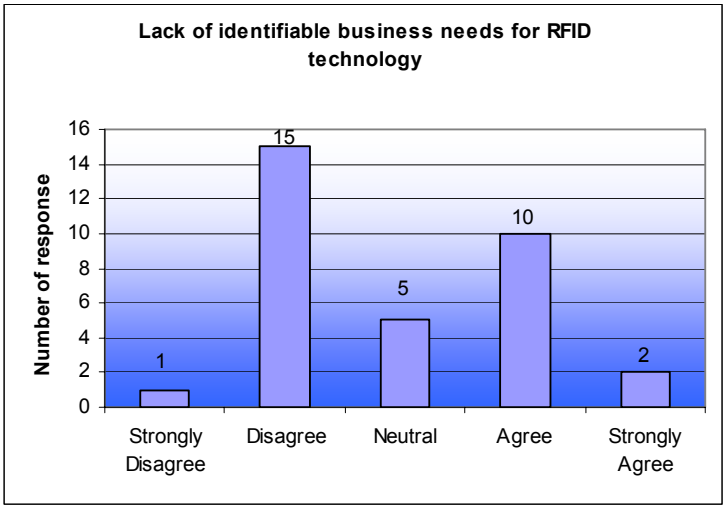

Figure 51: A lack of identifiable business needs for RFID technology

Figure 51 indicates that the majority of respondents (45.5%) disagree and 3% strongly disagree, which makes a total of 48.5% of respondents who believe that a lack of identifiable business needs is not a barrier for RFID technology. There are 15.2% of respondents who neither agree nor disagree, 30.3% of respondents who agree and 6.1% of respondents who strongly disagree with this statement.

From the response, most respondents believe that a lack of identifiable business needs is not a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test

was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
184	$P_1 = 0.6869$	$P_2 = 0.322$

Table 66: Testing lack of identifiable business needs for RFID technology

Test Statement: A lack of identifiable business needs for RFID technology in the retail sector is a factor holding back RFID adoption
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 66 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.6869$ and $P_2=0.322$. Thus the author fails to reject the null hypothesis for both Test 1 and Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1 and Test 2. As a result, the response is not significantly different to neutral. Hence, the final conclusion from the statistical result shows the response neither agrees nor disagrees with the statement.

Therefore, there is no conclusive evidence indicating that a lack of identifiable business needs is or is not a barrier to RFID adoption in the retail sector

8.6.21 Hypothesis Set 21: The unwillingness of the customer and supplier to use it

H_{021}: The unwillingness of the customer and supplier to use RFID technology is not a barrier to RFID adoption in the retail sector

H_{121}: The unwillingness of the customer and supplier to use RFID technology is a barrier to RFID adoption in the retail sector

Question 29: *A lack of willingness to use RFID technology by the consumer and supplier is a barrier to RFID adoption in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	5	15.2%
Neutral	5	15.2%
Agree	16	48.5%
Strongly Agree	7	21.2%
Total	33	100.0%

Table 67: Lack of willingness to use RFID technology by the consumer and supplier

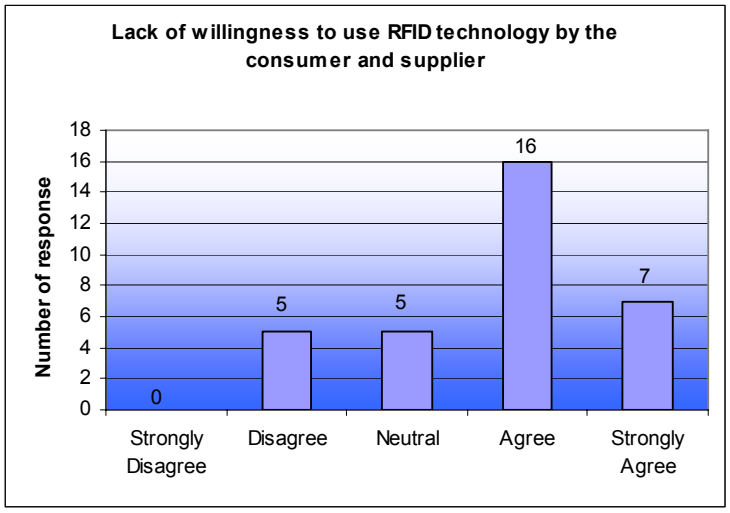

Figure 52: Lack of willingness to use RFID technology by the consumer and supplier

Figure 52 indicates that the majority of respondents (48.5%) agree and 21.2% strongly agree, which makes a total of 69.7% of respondents who believe that a lack of willingness to use RFID technology is a barrier. There are 15.2% of respondents who neither agree nor disagree and 15.2% of respondents disagree with this statement.

From the response, most respondents believe that a lack of willingness to use RFID technology by the customer and supplier is a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
351	$P_1 = 0.0002$	$P_2 = 0.9998$

Table 68: Testing lack of willingness to use RFID technology by the consumer and supplier is a barrier to RFID adoption

Test Statement: A lack of willingness to use RFID technology by the consumer and supplier is a barrier to RFID adoption in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 68 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.0002$ and $P_2=0.9998$. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 ($P_1=0.0002<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence that the unwillingness of the customer and supplier to use RFID technology is a barrier to RFID adoption in the retail sector.

8.6.22 Hypothesis Set 22: Lack of senior management support

H_{022}: Lack of senior management support is not a barrier to RFID adoption in the retail sector

H_{122}: Lack of senior management support is a barrier to RFID adoption in the retail sector

Question 30: *A lack of senior management support is holding back the adoption of RFID technology in the retail sector*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	12	36.4%
Neutral	8	24.2%
Agree	12	36.4%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 69: Lack of senior management support

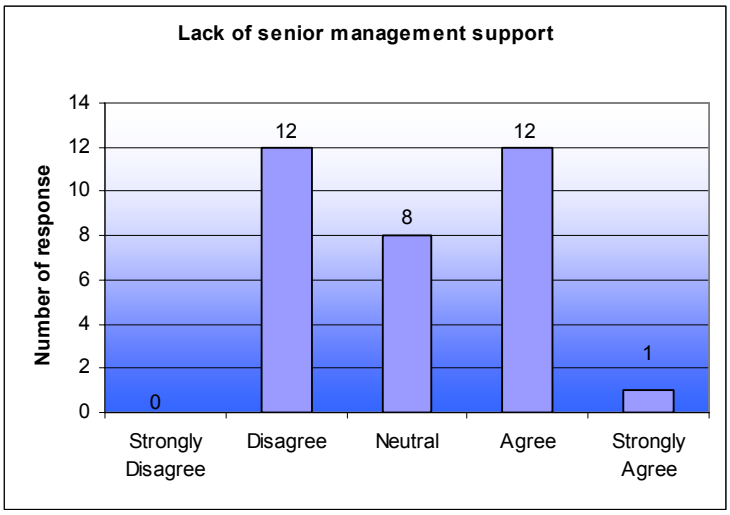

Figure 53: Lack of senior management support

Figure 53 indicates that 36.4% of respondents agree and 3% strongly agree, which makes a total of 39.5% of respondents who believe a lack of senior management support is a barrier for RFID technology. There are 24.2% of respondents who neither agree nor disagree and 36.4% of respondents who disagree with this statement.

From the response, there is no evidence to indicate whether or not the lack of senior management support is or is not a barrier, since the number of responses are

distributed evenly amongst disagree and agree. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
175	$P_1 = 0.3584$	$P_2 = 0.6529$

Table 70: Testing lack of senior management support

Test Statement: A lack of senior management support is holding back the adoption of RFID technology in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 70 shows the significant difference of Test 1 and Test 2, to be at $P_1=0.3584$ and $P_2=0.6529$. Thus the author fails to reject the null hypothesis for both Test 1 and Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1 and Test 2. As a result, the response is not significantly different to neutral. Hence, the final conclusion from the statistical result shows the response neither agrees nor disagrees with the statement.

Therefore, there is no conclusive evidence indicating that lack of senior management support is or is not a barrier to RFID adoption in the retail sector

8.6.23 Hypothesis Set 23: Lack of skilled personnel

H_{023}: Lack of skilled personnel is not a barrier to RFID adoption in the retail sector

H_{123}: Lack of skilled personnel is a barrier to RFID adoption in the retail sector

Question 31: *A lack of skilled RFID personnel is a barrier to RFID adoption*

	Count	*Percent*
Strongly Disagree	0	0.0%
Disagree	7	21.2%
Neutral	5	15.2%
Agree	20	60.6%
Strongly Agree	1	3.0%
Total	33	100.0%

Table 71: Lack of skilled RFID personnel

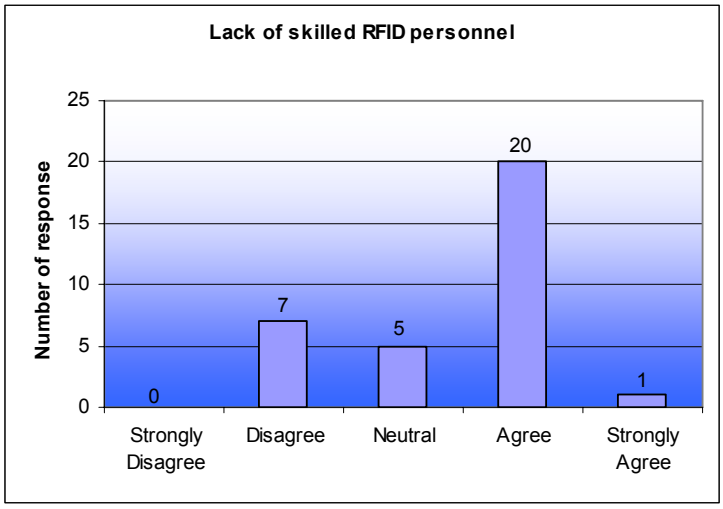

Figure 54: Lack of skilled RFID personnel

Figure 54 indicates that the majority of respondents (60.6%) agree and 3% strongly agree, which makes a total of 63.6% of respondents who believe that a lack of skilled RFID personnel is a barrier. There are 15.2% of respondents who neither agree nor disagree and 21.2% of respondents disagree with this statement.

From the response, most respondents believe that a lack of skilled personnel is a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was

used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
308	P_1= 0.003667	P_2=0.9966

Table 72: Testing lack of skilled RFID personnel is a barrier to RFID adoption

Test Statement: A lack of skilled RFID personnel is a barrier to RFID adoption.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 72 shows the significant difference of Test 1 and Test 2, to be at P_1=0.003667 and P_2=0.9966. Thus the author fails to reject the null hypothesis for Test 2, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 2. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 1 (P_1=0.003667<0.05), which means the author is highly confident that the alternative hypothesis, H_1 for Test 1 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response agrees with the statement.

Therefore, there is conclusive evidence that a lack of skilled personnel is a barrier to RFID adoption in the retail sector.

8.6.24 Hypothesis Set 24: Social influence

H_{024}: Social influence is not a barrier to RFID adoption in the retail sector

H_{124}: Social influence is a barrier to RFID adoption in the retail sector

Question 32: *Social issues surrounding RFID technology influence the adoption of RFID in the retail sector*

	Count	*Percent*
Strongly Disagree	1	3.0%
Disagree	15	45.5%
Neutral	9	27.3%
Agree	8	24.2%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 73: Social issues surrounding RFID technology is a problem

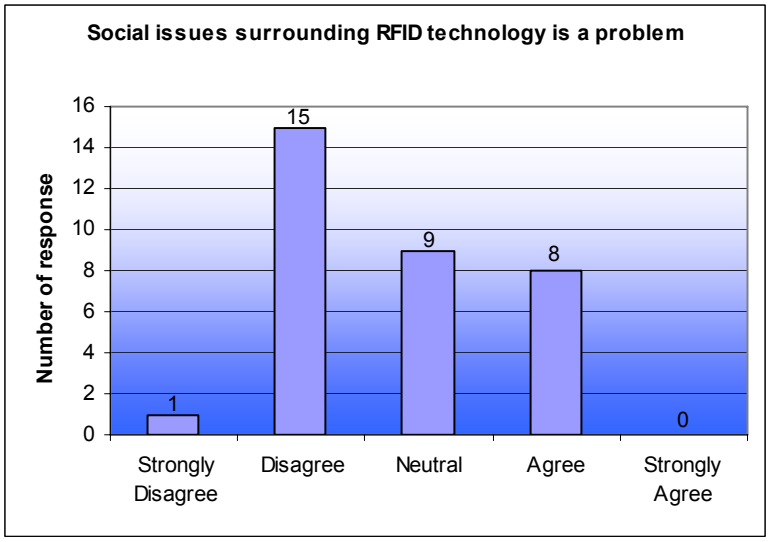

Figure 55: Social issues surrounding RFID technology is a problem

Figure 55 indicates that the majority of respondents (45.5%) disagree and 3% strongly disagree, which makes a total of 48.5% of respondents who believe that social issues surrounding RFID technology is not a barrier. There are 27.3% of respondents who neither agree nor disagree and 24.2% of respondents who agree with this statement.

From the response, most respondents believe social influence is not a barrier to RFID adoption. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ > 3 (agree and strongly agree)	$H_{0:}$ μ = 3 (neutral) $H_{1:}$ μ < 3 (disagree and strongly disagree)
96	P_1= 0.9598	P_2=0.04308

Table 74: Testing Social issues surrounding RFID technology is a barrier

Test Statement: Social issues surrounding RFID technology influence the adoption of RFID in the retail sector.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 74 shows the significant difference of Test 1 and Test 2, to be at P_1=0.9598 and P_2=0.04308. Thus the author fails to reject the null hypothesis for Test 1, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 2 (P_2=0.04308<0.05), which means the author is highly confident that the alternative hypothesis, H_1 for Test 2 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response disagrees with the statement.

Therefore, there is conclusive evidence that social influence is not a barrier to RFID adoption in the retail sector.

8.6.25 Hypothesis Set 25: The effect of radio emissions on personal health

H_{025}: The effect of radio emissions on personal health is not a barrier to RFID adoption in the retail sector

H_{125}: The effect of radio emissions on personal health is a barrier to RFID adoption in the retail sector

Question 33: *The impact of RFID technology on human health is a factor holding back the adoption of RFID technology*

	Count	*Percent*
Strongly Disagree	5	15.2%
Disagree	18	54.5%
Neutral	9	27.3%
Agree	1	3.0%
Strongly Agree	0	0.0%
Total	33	100.0%

Table 75: Impact of radio emission on human health is a barrier

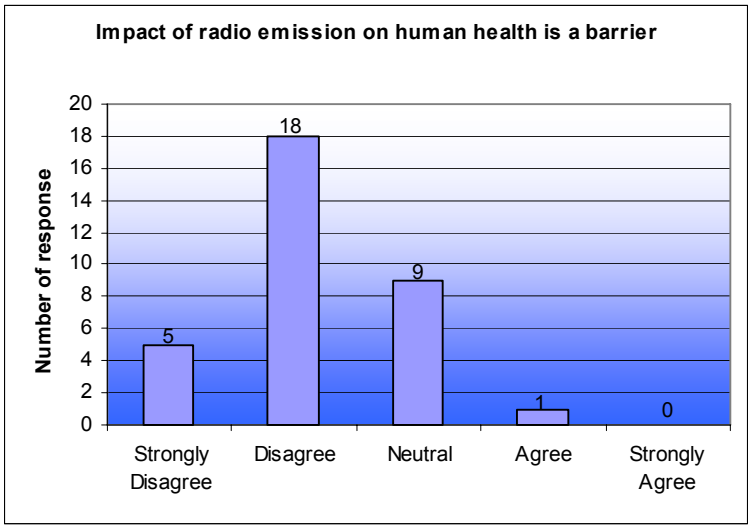

Figure 56: Impact of radio emission on human health is a barrier

Figure 56 indicates that the majority of respondents (54.5%) disagree and 15.2% strongly disagree, which makes a total of 69.7% of respondents who believe that the impact of RFID technology on human health is not a factor which influence the adoption of RFID. There are 27.3% of respondents who neither agree nor disagree and 3% of respondents agree with this statement.

From the response, most respondents believe radio emissions on personal health are not a barrier to RFID adoption in the retail sector. The Wilcoxon Signed Rank test was used to confirm this finding, and the following two tests were performed on this hypothesis:

	Test 1:	**Test 2**
Wilcoxon Value	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu > 3$ (agree and strongly agree)	$H_{0:}\ \mu = 3$ (neutral) $H_{1:}\ \mu < 3$ (disagree and strongly disagree)
10	$P_1 = 1$	$P_2 = 0.00001$

Table 76: Testing impact of radio emission on human health is a barrier

Test Statement: The impact of RFID technology on human health is a factor holding back the adoption of RFID technology.
Test 1: determines if the response is neutral or agrees with the statement.
Test 2: determines if the response is neutral or disagrees with the statement.

Table 76 shows the significant difference of Test 1 and Test 2, to be at $P_1=1$ and $P_2=0.00001$. Thus the author fails to reject the null hypothesis for Test 1, which means that there is not sufficient evidence against H_0 in favour of H_1 for Test 1. As a result, the response is not significantly different to neutral. However, the author successfully rejected the null hypothesis for Test 2 ($P_2=0.00001<0.05$), which means the author is highly confident that the alternative hypothesis, H_1 for Test 2 is accepted, and that the response is significantly different to neutral. Hence, the final conclusion from the statistical result shows the response disagrees with the statement.

Therefore, there is inconclusive evidence that radio emission on personal health is a barrier to RFID adoption in the retail sector.

8.7 Summary

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Technological	1	Lack of technological usefulness and advantageousness	No
	2	Lack of a business case	No
	3	Lack of global standards	Yes
	4	Not suitable for product assortment	No
	5	Poor tag reader accuracy and rates	Yes
	6	Large amount of data would swamp the business	No
	7	Complexity of technology	No
Cost and ROI	8	The high cost of hardware and infrastructure	Yes
	9	The high cost of software, integration, service, and support	Yes
	10	The high cost of tags	Yes
	11	Unclear ROI	Yes
Privacy and Security	12	Customer privacy concerns	Neutral
	13	Security concerns	Neutral
Implementation	14	Compatibility and integration with other technology	Yes
	15	Implementation challenges	Yes
	16	The need to fix data synchronisation first	No
	17	RFID authentication challenges	Neutral
Organisational	18	A high degree of business process change required	Yes
	19	Lack of awareness	Yes
	20	A lack of identifiable business needs	Neutral
People	21	The unwillingness of the customer and supplier to use it	Yes
	22	Lack of senior management support	Neutral
	23	Lack of skilled personnel	Yes
Environmental	24	Social influence	No
	25	The effect of radio emissions on personal health	No

Table 77: Summarised results of statistical analysis

Table 77 provides a summary of statistical analysis on each question derived from the corresponding hypothesis. The summary shows responses from various retailers in South Africa regarding RFID adoption barriers.

8.8 Conclusion

This chapter focused on the actual findings of the survey and reported on the various statistical analyses used to determine the validity of the conceptual framework developed in Chapter 7. The results obtained from the survey clearly demonstrate that the proposed conceptual framework is valid. However, some modification might be required according to the responses from the survey, given that it reveals perceptions held by members of the SA retail sector on the barriers to RFID adoption within that sector. From the statistical analysis, there is sufficient evidence to suggest that the majority of the barriers identified in Chapter 7 are pertinent to the adoption of RFID technology within the retail sector in South Africa.

Based on the finding of this study, an enhanced framework on the barriers of RFID adoption in the South African retail sector is presented in Chapter 9.

Chapter 9

Enhanced Framework of the Barriers of RFID Adoption in the South African Retail Sector

The previous chapter statistically analysed the results of the survey on RFID adoption barriers. This chapter presents an enhanced framework of the barriers to RFID adoption in South African retail sector.

9.1 Introduction

Statistical analysis in the previous chapter revealed that RFID technology is still financially, technically and operationally infeasible for retailers. The analysis of the results confirms some of the barriers identified in the literature review. However, there are factors which are not perceived as barriers to RFID adoption by the South African retail sector. These barriers have been discarded from the framework.

RFID promise to solve many problems, yet at the same time it presents a new set of problems and issues. In Chapter 6, a conceptual framework of the barriers of RFID adoption was proposed, which can now be revised in light of the results. In this chapter, key issues and implications associated with RFID adoption were highlighted, based on the analysis of the results and the literature review provided in the previous chapters. Findings on this thesis will provide a set of factors to be considered when deploying RFID technology.

9.2 Findings and Discussions

RFID technology faces many challenges. Some are systematic, and others are as a result of negative perceptions. In order to implement RFID systems successfully, we need to understand some of the key barriers that hinder RFID adoption.

Discussions on the statistical analysis in line with the conceptual framework of RFID adoption barriers are presented below:

9.2.1 Technological Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Technological	1	Lack of technological usefulness and advantageousness	No
	2	Lack of a business case	No
	3	Lack of global standards	Yes
	4	Not suitable for product assortment	No
	5	Poor tag reader accuracy and rates	Yes
	6	Large amount of data would swamp the business	No
	7	Complexity of technology	No

Table 78: Technological constraints for RFID adoption

According to the statistical results, South African retailers do not perceive most technological constraints, identified in the literature review, as barriers to the adoption of RFID. It is believed that as RFID technology matures, potential adopters would recognise the reality of the technology and the benefits it can bring to a business. As a result of RFID knowledge growth, some constraints are not considered as critical as they were previously. Table 78 shows the response gathered from the South African retail sector regarding technological aspects of RFID adoption barriers.

9.2.1.1

Hypothesis Set 1: Lack of technological usefulness and advantageousness

The research reveals that most South African retailers are aware of the usefulness and advantages offered by RFID technology. There is common recognition amongst retailers on as to the potential usefulness and advantages offered by RFID technology. The most prominent advantage is replenishment improvement, fraudulent goods detection and streamlining self-checkout process. As a result, lack of technological usefulness and advantageousness is not seen as a barrier to RFID adoption.

9.2.1.2

Hypothesis Set 2: Lack of a business case

In recent years, there have been numerous well publicised RFID implementations from some of the world's major retailers such as Wal-Mart, Albertsons, Tesco and Metro. Various research organisations and researchers have published a wide range of reports, white papers and case studies based on experiences from these companies. This information is available to the public for better understanding about the issues surrounding RFID adoption. As a result, there are adequate business cases available for RFID adoption in the retail sector, which could be utilised by South African retailers. Thus, a lack of business case is not perceived by SA retailers to be a barrier to RFID adoption.

9.2.1.3

Hypothesis Set 3: Lack of global standards

There is general consensus on the lack of global standards for RFID adoption by the retail sector. Currently, two major RFID standards exist; namely, EPCglobal and ISO. Unfortunately, there is no agreement amongst retailers on which standard to adopt in

South Africa. There is furthermore a lack of regulation or guidance from the government on which standards should be followed when implementing RFID technology in South Africa. Hence, retailers are uncertain as to which standard to commit to. Uncertainty about the future direction of RFID standards is without doubt a factor causing retailers to hold back on the adoption in South Africa. Lack of global standards is seen as a barrier to RFID adoption.

9.2.1.4

Hypothesis Set 4: Not suitable for product assortment

The majority of retailers recognise that RFID technology is best for product classification and assortment, given that it does not require line of sight and has long read ranges compared to traditional identification methods, such as barcode technology. It is acknowledged that RFID technology will work more efficiently and effectively than other technology, particularly when used for stock management. Thus, this factor is not a barrier to RFID adoption, and should be recognised as an advantage for RFID adoption in the retail sector.

9.2.1.5

Hypothesis Set 5: Poor tag reader accuracy and rates

The majority of SA retailers consider poor tag reader accuracy and tag read rates as a drawback of the technology. This barrier will have a direct impact on product detection, and as a result, retailers are concerned that the problem could cause direct financial losses and inaccurate data. Hence poor tag reader accuracy and rates are a barrier to RFID adoption in the SA retail sector.

9.2.1.6

Hypothesis Set 6: Large amount of data would swamp the business

The majority of retailers believe that data collected from transactions and stock control is manageable, and will provide additional value if processed for data mining. This also depends on the amount of data being kept in an RFID tag that is then transferred to the business. Most tags will contain only the minimum amount of information that is necessary to identify a particular product. Hence, the majority of SA retailers do not believe there will be a significant increase in the amount of data.

As a result, the large amount of data gathered from RFID systems is not considered a barrier to RFID adoption in the SA retail sector.

9.2.1.7

Hypothesis Set 7: Complexity of technology

According to SA retailers, RFID technology is considered to be very simple and easy to use. Respondents believe that employees and customers should be able to use RFID systems without much difficulty, because all the processes should be taken care of by the system and processed automatically without any human intervention. Hence, the complexity of the technology is not considered to be barriers to RFID adoption.

9.2.2 Cost and ROI Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Cost and ROI	8	The high cost of hardware and infrastructure	Yes
	9	The high cost of software, integration, service, and support	Yes
	10	The high cost of tags	Yes
	11	Unclear ROI	Yes

Table 79: Cost and ROI constraints for RFID adoption

Cost and ROI are considered key determinants as to whether or not to adopt RFID technology. Currently, the high prices of RFID systems including all hardware, software and tags make it hard to see an immediate return on investment. As a result, retailers will not rush in without first researching the best RFID strategy suitable for their requirements. Certainly, most SA retailers view RFID adoption from a business standpoint, not just a technological one; thus, examining the cost and return on investment is critical for adopting RFID technology.

9.2.2.1

Hypothesis Set 8, 9, 10: High cost constraints

Table 79 clearly shows that all three cost factors are barriers to RFID adoption. Most South African retailers believe that the current price of RFID hardware, infrastructure, software, integration, service, support and tags are relatively high, and therefore place

a heavy burden on the potential adopters in terms of initial cost. Even though RFID technology cost has dropped significantly over the past several years, especially the cost of the RFID tag, it is still higher than the retailers would like. Hence, cost is a key barrier to RFID adoption in South Africa.

9.2.2.2

Hypothesis Set 11: Unclear ROI

Return on investment is another factor considered by every retailer when considering RFID adoption. The cost-benefits of RFID adoption are clearly a major influence on return on investment, since most retailers will consider RFID adoption only if there are concrete benefits for the business. One of the dominant benefits that most retailers examine is cost reduction and profit growth, but because of the high costs of RFID technology, it is difficult to achieve this objective. Hence, one of the major contributions to unclear ROI is the high cost of RFID. As a result, unclear ROI are considered as a barrier to RFID adoption.

9.2.3 Privacy and Security Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Privacy and Security	12	Customer privacy concerns	Neutral
	13	Security concerns	Neutral

Table 80: Privacy and security constraints for RFID adoption

It is interesting to note from the results that privacy and security issues surrounding RFID technology remain neutral, which indicates that SA retailers are undecided whether or not privacy and security is or is not a barrier to RFID adoption. This is contrary to the findings from the literature review, which indicates that most researchers and research organisations have identified privacy and security issues as a key barrier. The following insight is offered as to why South African retailers do not currently consider privacy and security as a barrier:

9.2.3.1

Hypothesis Set 12: Customer privacy concerns

Customer privacy concerns are mostly raised by privacy advocates abroad who do not have a major influence in South Africa. It is believed that the majority of customers in South Africa are not currently aware of the next generation of identification technology, such as RFID, let alone the privacy implications this may have on their lives. As a result of this lack of awareness, retailers are not under pressure to address this potential privacy concern. But as general public awareness increases, South African retailers, like their counterparts in other countries will have to give this factor more attention. Hence, customer privacy should be a factor to consider in RFID adoption.

9.2.3.2

Hypothesis Set 13: Security concerns

A concern about security is somewhat related to privacy. It is about how to keep RFID information safe from hackers or intruders, rather than concentrating on securing customer information, hence, it is more focused internally in the business. It is believed that one of the main reasons SA retailers are not concerned about RFID security is that there are currently no major threats against RFID technology, particularly in South Africa. As RFID technology gains in popularity amongst individuals, retailers and in other marketplaces, security will become increasingly important, while individuals try to exploit this technology for their own benefits. As a result, security concerns will heighten over time.

The survey revealed that responses to privacy and security questions were distributed almost evenly amongst those who agree, those who are neutral and those who disagree; hence, there is no evidence to suggest that privacy and security is not a concern. As previously discussed, when consumers and retailers gain a greater awareness of RFID technology, and the install base increases, so will security risks increase as exploiters realise on the value of data contained within these systems. Hence, it is believed that customer privacy concerns and security concerns should not be discarded as barriers, and must be included in the framework.

9.2.4 Implementation Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Implementation	14	Compatibility and integration with other technology	Yes
	15	Implementation challenges	Yes
	16	The need to fix data synchronisation first	No
	17	RFID authentication challenges	Neutral

Table 81: Implementation constraints for RFID adoption

Implementation constraints are clearly potential barriers to wide-scale deployment. According to the results, two out of four factors investigated under the implementation constraints are confirmed to be barriers to RFID adoption by SA retailers. Of the remaining two factors, one is not considered a barrier and the other one is neutral. How retailers view the difficulty of implementing RFID is a critical aspect to be measured by retailers that intended to mandate RFID technology in their business. A strategic approach to RFID implementation at the initial stage is vital for successful adoption.

9.2.4.1

Hypothesis Set 14: Compatibility and integration with other technology

SA retailers perceive compatibility and integration with other technology to be a barrier. It is believed that RFID technology must be able to integrate with current systems in the business for maximum benefit. Without this, retailers are unlikely to adopt RFID. Retailers currently experience difficulty in trying to integrate current IT systems such as Enterprise Resource Planning (ERP) systems, Customer Relationship Management (CRM) systems and Electronic point-of-sale (POS) systems. RFID could indeed compound integration complexity and retailers have expressed concern about this. There is no one-size-fits-all solution and as a result, every RFID integration case must be dealt with individually to fit the conditions of the business. Thus, compatibility and integration is a factor that must be considered as a barrier to RFID adoption.

9.2.4.2

Hypothesis Set 15: Implementation challenges

RFID is an evolving technology, and in order to achieve a successful RFID implementation, the potential adopter needs to face a multitude of implementation challenges. These challenges entail managing RFID implementation projects and overcoming difficulties that arise along the way. Hence, South African retailers also perceive implementation challenges as a barrier to adopting RFID.

9.2.4.3

Hypothesis Set 16: The need to fix data synchronisation first

The research findings revealed that data synchronisation issues are not considered a barrier to RFID adoption, because most retailers believe RFID systems should only create and collect useful data in the field and bring that data back to other systems in a compatible format. Hence, data synchronisation is not a barrier to RFID adoption.

9.2.4.4

Hypothesis Set 17: RFID authentication challenges

Retailers are generally neutral about RFID authentication challenges which indicates that the retailers are either unaware of RFID authentication or that there is a lack of consideration of this issue at the time of writing. It is believed that the RFID industry is working hard to build reliability into the infrastructure, and the important step is to build trust. However, current discussions have focused on privacy issues, and there is a lack of awareness about authentication. The current practice for RFID authentication is 'track and trace', which detects cloned tags and kills the tag outside the retail environment, so that no one would be able to obtain any information from the tag, post-purchase. Authentication is an important part of building trust for future RFID applications; perhaps not for basic tags currently, but over time requirements will grow as new applications are enabled. As a result, authentication is not discarded from the framework and should be considered a barrier.

9.2.5 Organisational Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Organisational	18	A high degree of business process change required	Yes
	19	Lack of awareness	Yes
	20	A lack of identifiable business needs	Neutral

Table 82: Organisational constraints for RFID adoption

An examination of the impact of organisational constrains on RFID adoption revealed that a high degree of business process change and lack of awareness are barriers. It is also interesting to note that the answer to 'no identifiable business need' is neutral, which means that there is no evidence to determine whether this factor is a barrier or not.

9.2.5.1

Hypothesis Set 18: A high degree of business process change required

RFID adoption requires a high degree of business process change as perceived by SA retailers, since existing business process is inadequate to carry out successful business activities and this challenges business mangers to rethink RFID deployment. It is recognised that the best and most practical way to maximise an RFID investment is to adjust business processes while business is continuing. Hence, a high degree of business process change must be considered as an organisational constraint for RFID adoption.

9.2.5.2

Hypothesis Set 19: Lack of awareness

The result showed that a major drawback to wide-spread deployment of RFID systems is the lack of awareness and knowledge. The lack of awareness of RFID and the potential benefits of RFID technology amongst South African retailers were recognised as a barrier. It is believed that the level of awareness is certainly rising amongst IT professionals and some senior managers in South Africa, but the majority of executive board members and senior managers are still unaware of such technology, and these people are the ones involved in making key decisions for the business.

Therefore, retailers will not invest in a technology that is unfamiliar and has many unknowns. Hence, lack of awareness is a factor holding back RFID initiatives.

9.2.5.3

Hypothesis Set 20: A lack of identifiable business needs

There were no clear indications as to whether or not identifiable business need is a barrier, as the responses were evenly distributed amongst those who agreed and those who disagreed. However, it is believed that there are clear business needs for RFID technology in the retail sector, as it would:

- improve re-stocking and replenishment
- reduced the need to check merchandise carried by customers into the store
- track merchandise removed from the shelf
- reject counterfeit or fraudulent goods
- streamline the process of self-checkout and
- assist in dynamic pricing.

It was confirmed previously that South African retailers consider RFID technology to be useful, and it does provide advantages over traditional barcode systems. As a result, there was some consensus on the need for RFID technology, and so business need is not considered a barrier to RFID adoption in the retail industry.

9.2.6 People Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
People	21	The unwillingness of the customer and supplier to use it	Yes
	22	Lack of senior management support	Neutral
	23	Lack of skilled personnel	Yes

Table 83: People constraints for RFID adoption

As indicated in Table 83, two factors were believed to be barriers identified under the category of 'People Constraints'. This is an important category for retailers to consider when intending to adopt RFID technology. It is believed that individuals' attitudes have a major impact on the adoption of RFID, and this should be considered as a key issue.

9.2.6.1

Hypothesis Set 21: The unwillingness of the customer and supplier to use it

The customers' and suppliers' lack of willingness to use the technology was a general concern for RFID adoption, and most retailers believe that this is a major adoption impediment. The reason is that retailers alone would not gain maximum benefits from a closed RFID system, since the scope of application of a closed system is limited within a single organisation. There are a multitude of benefits to be derived by an organisation integrating RFID across the supply chain, as discussed in the literature review. These benefits would positively impact risk and costs while increasing efficiency and success. Hence, an unwillingness of the customer and supplier to use the technology is a barrier to RFID adoption.

9.2.6.2

Hypothesis Set 22: Lack of senior management support

Surprisingly the response from SA retailers on the issue concerning lack of senior management support did not clearly indicate whether or not this factor is a barrier to RFID adoption. However, it is believed that a major drawback to wide-spread deployment of RFID systems is people's overall attitude towards the technology. Many researchers have shown that lack of support is a problem, and should be

addressed accordingly. A possible reason for this research outcome could lie in the nature of the targeted respondents, as most respondents, if not all, were IT professionals, who are more likely to understand and support RFID adoption than other senior management who do not have the same insight. Furthermore, a lack of awareness, as identified earlier, indicates that in general, retailers have insufficient knowledge about RFID, and as a result, would not support its adoption. Hence a lack of senior management support has not been discarded from the framework and is considered a barrier to RFID adoption.

9.2.6.3

Hypothesis Set 23: Lack of skilled personnel

RFID-knowledgeable personnel are hard to find. Many SA retailers, regardless of size, would discover they have no qualified RFID personnel. Hence, retailers believe there are not enough RFID experts with sufficient knowledge in the field to facilitate RFID adoption. It is believed that lack of expertise is a barrier causing many SA retailers to hold back on RFID adoption. Without expert skills, retailers might end up spending too much time and money on an RFID project, possibly leading to its failure. Hence, SA retailers regard the lack of skilled personnel as a barrier to RFID adoption.

9.2.7 Environmental Constraints

Area of Constraints	Hypothesis Set	Factor Analysis of Perceived RFID Barriers	Statistical Result: is or is not a barrier
Environment	24	Social influence	No
	25	The effect of radio emissions on personal health	No

Table 84: Environmental constraints for RFID adoption

The research revealed that respondents do not currently perceive environmental factors as barriers.

9.2.7.1

Hypothesis Set 24: Social influence

As discussed in Chapter 4, social influence (subject norm and social factors) could impact the adoption of a new technology. However, most retailers suggest that social

influence is not a barrier to RFID adoption, indicating that their attitudes towards RFID technology will not be easily influenced by others. Instead, retailers will probably tend to focus on official reports and case studies that examine the reality of RFID technology. Hence, social influence is not a barrier to RFID adoption.

9.2.7.2

Hypothesis Set 25: The effect of radio emissions on personal health

RFID technology uses radio waves (radio emissions) to transmit data from tags to readers, and according to Table 84, the effects of radio emissions on health is not a barrier to its adoption. There is currently no evidence indicating that radio emissions from RFID would pose a health risk. Therefore, SA retailers were not worried about the effects of RFID on health and do not regard the effect of radio emissions on personal health as a barrier to RFID adoption.

Given the existing minimal install base of RFID in South Africa and the resultant lack of public knowledge and understanding of the technology, it is believed that environmental issues which include social influence as well as health concerns have not really been explored in South Africa. There is evidence of some of these concerns being explored in the international market. However, within the South African context, these issues are not considered to be barriers to RFID adoption.

9.3 Summary

There are 16 barriers identified to be stumbling blocks to RFID adoption in the South African retail sector. These barriers are grouped according to areas of constraint and are illustrated in Table 85 in terms of an enhanced framework. The framework of RFID adoption barriers are sorted according to each category (area of constraints), rather than importance. This framework is an outline of the barriers impacting RFID adoption in the SA retail sector that need to be addressed.

Area of Constraints	RFID adoption Barriers
Technological	Lack of global standards Poor tag reader accuracy and rates
Cost and ROI	The high cost of hardware and infrastructure The high cost of software, integration, service, and support The high cost of tags Unclear ROI
Privacy and Security	Customer privacy concerns Security concerns
Implementation	Compatibility and integration with other technology Implementation challenges RFID authentication challenges
Organisational	A high degree of business process change required Lack of awareness
People	The unwillingness of the customer and supplier to use it Lack of senior management support Lack of skilled personnel

Table 85: Enhanced Framework of the Barriers to RFID adoption in the South African Retail Sector

9.4 Conclusion

An RFID adoption barrier represents the major adoption obstacles that must be identified, understood, and as far as possible, overcome, in order for South African retailers to consider adopting RFID technology. The literature review indicates that there are numerous factors to be considered in RFID adoption. This chapter discussed the factors believed to be RFID adoption barriers pertaining to the South African retail sector. Barriers that were identified to be impediments were highlighted and recognised as such. An enhanced framework summarising the pertinent barriers is proposed, which provides an overview of the essential key factors influencing RFID adoption in the South African retail sector. These barriers are grouped into six categories, namely Technological, Cost and ROI, Privacy and Security, Implementation, Organisational and People. Each category contains two or more barrier factors that impact RFID adoption, which need to be considered and addressed.

Chapter 10

Conclusion and Future Research

The previous chapter presented an enhanced framework of the barriers to RFID adoption in the South African retail sector. This chapter concludes the research by presenting contributions of the research and suggestions for future research.

10.1 Introduction

RFID is one of the fastest growing technologies today because it can uniquely identify a person, item, or location, using radio wave technology without the need for line-of-sight. RFID technology also enables efficient recording and gathering of information on routine operations and processes by suitably placed readers that automatically record data stored on a tag. More detailed real-time information leads to better planning, and optimisation can assist retailers to optimise their supply chains.

In recent years, RFID has increasingly gained attention due partly to international retailers committing to this technology. While RFID technology shows much potential, there are numerous barriers that need to be considered before this technology is adopted. It is vital to understand what the retail sector regard as adoption barriers, so that potential adopters can avoid or overcome them. This research investigated the diffusion of innovation and RFID adoption challenges identified by various researchers and research organisations. A proposed framework was constructed and tested to determine what the SA retail sector regards as barriers to RFID. This chapter concludes the findings by summarising the contributions of this research and proposing areas of future research.

10.2 Contributions of the Research

The following issues were highlighted as a result of this investigation:

- The retail sector performs a vital part in the South African economy. Currently barcode technology is the predominant AIDC technology; however, retail supply chain management are aware of the need to enhance their supply chain efficiency to stay competitive. This research revealed that retail supply chain management can demonstrate a basic knowledge of alternative technologies such as RFID.

- Many theories and models are used to identify various factors influencing the disapproval/approval of an innovation, such as RFID technology. Applying the theories and models, and understanding what these factors are, could assist us to predict the likely rate of adoption of an innovation - in this case, RFID

technology in the South Africa retails sector. The theories and their related factors, as discussed in detail in Chapter 4, are listed below:

- Diffusion of innovation theory: relative advantage, compatibility, complexibility, trialability, and observability.
- Adoption of information technology innovation theory: relative advantage, ease of use, image, visibility, compatibility, results demonstrability, and voluntariness of use.
- Theory of reasoned action: attitude towards behaviour, and subjective norm.
- Extended Social Cognitive Theory: outcome expectation, self-efficacy, affect, anxiety.
- Technology acceptance model: perceived usefulness, perceived ease of use.
- Theory of planned behaviour: attitude toward act or behaviour, subjective norm, perceived behavioral control.
- Model of personal computer utilisation: job-fit, complexity, long-term consequences, affect towards use, social factors, facilitating conditions.

- SA retailers understand the usefulness and advantage that RFID technology brings to the retail sector, which will benefit both the customer and the business. They are aware that there are RFID business cases available in the international retail sector that could be utilised for an in-depth understanding on RFID adoption.

- There is general concern amongst SA retailers regarding multiple standards in RFID adoption, namely ISO and EPCglobal. SA retailers are uncertain of which standard to follow, because choosing a wrong standard might have a major impact on the organisation down the line.

- SA retailers view RFID as a suitable technology for product assortment, given its automatic identification capability. Every item that enters or exits the store can potentially be recorded automatically without any human intervention. In

addition, it can make the process of assorting, distribution and classification of items much quicker and more efficient.

- Poor tag reader accuracy and the read rate is a concern to SA retailers. Since information recording is done automatically using RFID technology, it is crucial that information is recorded accurately and quickly. Inaccurate data can easily be ignored with the automatic process, which may cause delay and expensive manual interventions.

- SA retailers believe that RFID technology does not generate a large amount of data that can not be handled. In fact, retailers believe that they can benefit from the additional data that provides them with greater information, to offer better customer service.

- The simplicity of RFID technology use is regarded as a benefit for stock control and the customer shopping experience. SA retailers are aware that RFID systems can detect items automatically, which may simplify the point-of-sale process.

- The high costs associated with RFID technology is a major concern for SA retailers. These costs include the cost of hardware, software, integration, service, support and the RFID tag itself. These costs may negatively impact the cost of products, which could ultimately lead to a loss in competitive advantage.

- The majority of SA retailers have not yet piloted RFID in their organisation, and are therefore uncertain about the return on investment in RFID technology. Unfortunately, without a clear understanding of ROI, SA retailers are reluctant to adopt an RFID initiative.

- SA retailers are not concerned about RFID privacy and security implications on the customer and the organisation. These issues are investigated broadly in the international marketplace, as they have a major impact on safety of the

information pertaining to both the customer and organisation. Furthermore, SA retailers are currently not considering RFID authentication, because of this lack of concern with privacy and security.

- SA retailers are aware of the obstacles surrounding compatibility and the integration of RFID technology. RFID technology must integrate with other systems to provide maximum benefits, and as a result, a high degree of business process change is required.

- Implementation challenges associated with RFID adoption are a concern for the SA retailer. The success of RFID adoption depends on how these implementation challenges can best be overcome.

- SA retailers are not considering data synchronisation as a problem in RFID adoption. Retailers believe that the information gathered from RFID systems would most probably be in the same format as information gathered in barcode systems, that is, a unique identification number.

- SA retailers believe that there is a lack of awareness about RFID technology, which consequently results in fewer RFID initiatives. However, most retailers think that as RFID technology gains more popularity, more retailers will become involved in the development of RFID initiatives.

- SA retailers believe there is a lack of willingness by supply chain partners to use RFID technology. A lack of acceptance from these partners will retard RFID adoption, as the real benefits to RFID adoption, as previously discussed, are to be gained by integration across the entire supply chain.

- Lack of senior management support is recognised as a problem in RFID adoption among SA retailers. Senior management are in a difficult position when deciding on RFID adoption, as there are numerous challenges that hinder the success and outcome. As a result, most senior managers are not supportive of RFID adoption.

- One of the barriers considered by SA retailers is the shortage of skilled RFID personnel. It is crucial to have experienced RFID professionals in the adoption stage to ensure success. In addition, knowledgeable staff are needed to operate RFID systems after implementation. Given the general lack of skills in the SA marketplace, this could adversely effect RFID adoption.

- SA retailers believe that both social influence and the effect of radio emissions on health are not a consideration for RFID adoption, and therefore, not an obstacle.

- The majority of the factors proposed as barriers to RFID adoption were confirmed by South African retailers, and therefore, should be considered and addressed when adopting RFID technology, particularly within this sector. An enhanced framework of the barriers that influence the adoption of RFID in the South African retail industry was provided. These include technological constraints, cost and ROI constraints, privacy and security challenges, implementation challenges, organisational concerns, and people constraints.

10.3 Future Research

Once barriers to RFID adoption in the South African retail sector are recognised and understood, it is essential to make some recommendations on how to overcome these barriers in order for SA retailers to successfully adopt RFID technology.

As mentioned in the research, RFID adoption is costly, and therefore most retailers cannot afford to implement such technology. Hence a lightweight RFID framework could be developed to provide SA retailers with a low-cost, lightweight version that is separate from existing IT and that can enhance inventory control and point-of-sale process.

One of the limitations in this research is the lack of complete and detailed analysis of one or two case studies on the adoption of RFID in the SA retail sector. This is understandable as no major retailer has yet adopted RFID technology. However, through this study, it is evident that several major retailers are considering piloting or

adopting RFID technology within the next two years. Once this has happened, it would be greatly beneficial to conduct an in-depth case study on such an adoption.

In addition, there are numerous RFID mandates around the world, specifically in the retail sector, such as Wal-Mart. Albertsons, Tesco and Metro. It would be valuable to identify common adoption characteristics and practices, and then formulate some guidelines or best practices on RFID adoption for the retail sector, particularly in the South African context.

10.4 In Closing

It seems possible that Radio Frequency Identification (RFID) could become the preferred supply chain management technology in future retail systems. While the benefits of RFID are understood and accepted by most senior management within the South African retail sector, there are multitudes of challenges regarding RFID that must first be overcome, namely:

- Lack of global standards
- Poor tag reader accuracy and rates
- The high cost of hardware and infrastructure
- The high cost of software, integration, service, and support
- The high cost of tags
- Unclear ROI
- Customer privacy concerns
- Security concerns
- Compatibility and integration with other technology
- Implementation challenges
- RFID authentication challenges
- A high degree of business process change required
- Lack of awareness
- The unwillingness of the customer and supplier to use it
- Lack of senior management support
- Lack of skilled personnel

RFID is an innovative technology that promises to increase visibility, efficiency, safety, security, speed, and inventory control; and reduce labour hours in the retail sector. There are, however, adoption barriers and it is important to identify and understand these barriers, so that the necessary action can be taken to mitigate them.

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Appendix A

List of Organisations Surveyed

Organisations	Retailers
AVI Limited	I&J; NBL; DENNY; RBC; Indigo; A&D Spitz; Five Roses; Bakers; Ciro; Frisco; Willards; Real Juice; Kurt Geigner; Carvela; Yardley
CUM Books	CUM Books
DaimlerChrysler	DaimlerChrysler
Dunns	Dunns
Edcon	Boardmans; CAN; Edgars; Jet; Jet Mart; Jet Shoes; Legit; Prato; Red Square; Temptations
Ellerine Holdings Ltd	Ellerines; Town Talk Furnishers; Furncity; Lubners; Beares; Savells Fairdeal; Green & Richards; Furniture City; Dial-a-Bed; Mattress Factory; Roodefurn; Wetherlys; Osiers
Exclusive Books Group	Exclusive Books
The Foschini Group	Foschini; Donna-Claire; Fashion Express; Luella; Markham; Exact!; Sportscene; Totalsports; Duesouth; American Swiss; Sterns; Matrix; @home; TFG Apparel
Frame Leisure Trading	Cross Trainer
Futura Footwear Ltd	Bata
Glomail	Glomail
Homemark	Homemark

Organisations	Retailers
JD Group	Abra; Barnetts; Bradlows; Electric Express; Hi-Fi Corporation; Incredible Connection; Joshua Doore; Morkels; Price 'n Pride; Russells
Lewis Group Ltd	Lewis; Best Electric; Lifestyle Living
Look & Listen	Look & Listen
Massmart Holdings LTD	Game; Dion; Makro; Builders Warehouse; Builders Express; Builders Trade Dept; Jumbo; Shield
McCarthy Limited	Passenger Vehicle Franchises: Alfa Romeo, Audi, BMW/Mini, Cadillac, Chevrolet, Chrysler, Dodge, Fiat, Hummer, Isuzu, Jeep, Land Rover, Lexus, Mahindra, Mercedes-Benz, Mitsubishi, Nissan, Opel, Peugeot, Renault, SEAT, Smart, Tata, Toyota, Volvo, Volkswagen. Commercial Vehicle Franchises: Mercedes-Benz, Freightliner, Mitsubishi FUSO, Western Star, Toyota Trucks, Fiat, Nissan Diesel, Volkswagen.
Metcash Trading Africa (Pty) Ltd	Cash and Carry; Trade Centre; Liquor World; Stax; Friendly Distribution Centre
Mr Price Group	Mr Price; Mr Price Sport; Mr Price Home; Miladys; Sheet Street
New Clicks Holdings	Clicks; Musica; Discom; United Pharmaceutical Distributors (UPD); The Body Shop
Pepkor Holdings Limited	Shoe City; PEP; Ackermans; Best & Less; Pepco Poland; John Craig

Organisations	Retailers
Pick ‘n Pay Holdings	Pick ‘n Pay
The Platinum Group	Jenni Button; Hilton Weiner; Urban; Aca Joe; Vertigo
Queenspark (Pty) Ltd	Queenspark
Reggies	Reggies
SA Greetings	Cardies
Shoprite Holdings LTD	Shoprite; Checkers hyper; OK; OK Furniture; House & Home; Freshmark
Smart X Central Intelligence	Smart Technology (such as RFID) consultant for numerous retailers
Smollan Group SA (Pty) Ltd	Smollan Group
The Spar Group	Superspar; Kwikspar; Spar; Buildit
Toys “R” Us	Toys “R” Us
Truworths	Fashion; Truworths; Truworths Man; Inwear; Daniel Hechter; LTD; Fashion News
Woolworths Holdings	Woolworths

Appendix B

Questionnaire

Radio Frequency Identification (RFID) Survey

Perceptions held by members of the retail sector regarding the adoption constraints

Instructions: This survey consists of 37 questions and should take you approximately 5 to 10 minutes to complete. Please indicate whether or not you would like a compiled report of the research findings to be sent. Your participation is very much appreciated. Background Information: Radio Frequency Identification (RFID) is a technology that incorporates the use of electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum to uniquely identify an object, animal, or person. RFID is coming into increasing use in industry as an alternative to the bar code. The advantage of RFID is that it does not require direct contact or line-of-sight scanning. An RFID system consists of three components: an antenna and transceiver (often combined into one reader) and a transponder (tag).

Questions Begin: Please indicate whether you agree of disagree with each statement concerning the barriers to RFID adoption.

Questions marked with a * are required.

*1. Full Name:

*2. Organisation:

*3. Position:

- ○ CEO / CFO / CIO / Chairman / ..
- ○ President / Vice President
- ○ Managing Director
- ○ Department Manager
- ○ Other Manager
- ○ Senior Staff Member
- ○ Freelancer
- ○ Other

*4. Number of employees in your company:

- ○ Less than 10
- ○ 11 – 50
- ○ 51- 250
- ○ 251 - 500
- ○ More than 500

*5. Which of the following best describes the status of RFID adoption in your organisation?

- ○ Evaluating the possible use of RFID
- ○ Planning to launch a RFID pilot study
- ○ Planning to implement RFID
- ○ Currently implementing RFID
- ○ RFID already fully implemented
- ○ Not planning to implement RFID
- ○ No RFID-related activities

*6 If your organisation has not implemented RFID but expects to, when do you expect implementation to begin?

- ○ Immediately
- ○ Within the next twelve months
- ○ One to two years from now
- ○ More than two years from now
- ○ Not relevant

*7 How familiar are you with RFID technology?

- ○ Have never heard of it
- ○ May have heard it referred to
- ○ Somewhat familiar
- ○ Moderately familiar
- ○ Extremely Knowledgeable

*8. RFID technology would provide additional value if deployed within the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*9. There is a convincing business case for RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*10. A lack of RFID global standards is holding back the adoption of RFID technology in retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*11. RFID technology is suitable for product assortment in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*12. Poor reader accuracy is a barrier to RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*13. Poor read rate is a barrier to RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*14. RFID systems will generate too much data that will become difficult to manage.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*15. RFID systems are too complex for users, such as employees and consumers.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*16. The high cost of RFID hardware and infrastructure is a barrier to the adoption of RFID in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*17. The high cost of RFID software, integration, service, and support is a barrier to the adoption of RFID in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*18. The high cost of RFID tags is a reason causing retailers to hold back on the adoption of RFID technology.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*19. Uncertainty in return on investment for an RFID system is an obstacle in the adoption of RFID technology.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*20. The impact of consumer privacy is a concern for RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*21. RFID security is a concern in the adoption of RFID technology.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*22. Difficulties in compatibility and integration of RFID with other technology are a barrier to RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*23. Challenges relating to RFID implementation are a stumbling block in the adoption of RFID technology.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*24. Data synchronisation between RFID systems and other systems is a problem in RFID adoption.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*25. A lack of authentication in RFID systems and tags is a barrier to RFID technology adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*26. The high degree of business process change required for RFID adoption is an obstacle in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*27. A lack of awareness in RFID technology is holding back the adoption of RFID in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*28. A lack of identifiable business needs for RFID technology in the retail sector is a factor holding back RFID adoption.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*29. A lack of willingness to use RFID technology by the consumer and supplier is a barrier to RFID adoption in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*30. A lack of senior management support is holding back the adoption of RFID technology in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*31. A lack of skilled RFID personnel is a barrier to RFID adoption.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*32. Social issues surrounding RFID technology influence the adoption of RFID in the retail sector.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

*33. The impact of RFID technology on human health is a factor holding back the adoption of RFID technology.

- ○ Strongly Disagree
- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

34. Please leave any additional comments or questions below:

35. I would like to receive a compiled report on the findings of this survey.

- ○ Yes
- ○ No

36. Email Address:

37. Phone Number:

Submit Survey

Appendix C

Results of Questions 8 to 33

Results of Questions 8 to 33											
Question	**Strongly Disagree (1)**		**Disagree (2)**		**Neutral (3)**		**Agree (4)**		**Strongly Agree (5)**		***N***
	Count	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	
Q8	0	0.0	0	0.0	6	18.2	21	63.6	6	18.2	33
Q9	0	0.0	4	12.1	9	27.3	19	57.6	1	3.0	33
Q10	0	0.0	2	6.1	9	27.3	18	54.5	4	12.1	33
Q11	1	3.0	2	6.1	7	21.2	23	69.7	0	0.0	33
Q12	0	0.0	6	18.2	14	42.4	11	33.3	2	6.1	33
Q13	0	0.0	4	12.1	18	54.5	9	27.3	2	6.1	33
Q14	4	12.1	20	60.6	7	21.2	1	3.0	1	3.0	33
Q15	7	21.2	18	54.5	6	18.2	2	6.1	0	0.0	33
Q16	1	3.0	2	6.1	5	15.2	18	54.5	7	21.2	33
Q17	0	0.0	1	3.0	8	24.2	17	51.5	7	21.2	33
Q18	0	0.0	3	9.1	6	18.2	7	21.2	17	51.5	33
Q19	0	0.0	5	15.2	5	15.2	17	51.5	6	18.2	33
Q20	0	0.0	12	36.4	8	24.2	12	36.4	1	3.0	33
Q21	0	0.0	10	30.3	13	39.4	9	27.3	1	3.0	33
Q22	0	0.0	6	18.2	12	36.4	13	39.4	2	6.1	33
Q23	0	0.0	3	9.1	7	21.2	22	66.7	1	3.0	33
Q24	1	3.0	17	51.5	7	21.2	8	24.2	0	0.0	33
Q25	0	0.0	6	18.2	22	66.7	5	15.2	0	0.0	33
Q26	1	3.0	7	21.2	6	18.2	18	54.5	1	3.0	33
Q27	2	6.1	7	21.2	4	12.1	16	48.5	4	12.1	33
Q28	1	3.0	15	45.5	5	15.2	10	30.3	2	6.1	33
Q29	0	0.0	5	15.2	5	15.2	16	48.5	7	21.2	33
Q30	0	0.0	12	36.4	8	24.2	12	36.4	1	3.0	33
Q31	0	0.0	7	21.2	5	15.2	20	60.6	1	3.0	33
Q32	1	3.0	15	45.5	9	27.3	8	24.2	0	0.0	33
Q33	5	15.2	18	54.5	9	27.3	1	3.0	0	0.0	33

Results of the Basic Statistical Analysis									
Question	Mean	Median	Mode	Std. Dev.	Coef. Var.	Std. Err.	Minimum	Maximum	N
Q8	4.0000	4	4	0.6124	15.3093	0.1066	3	5	33
Q9	3.5152	4	4	0.7550	21.4794	0.1314	2	5	33
Q10	3.7273	4	4	0.7613	20.4246	0.1325	2	5	33
Q11	3.5758	4	4	0.7513	21.0099	0.1308	1	4	33
Q12	3.2727	3	3	0.8394	25.6475	0.1461	2	5	33
Q13	3.2727	3	3	0.7613	23.2613	0.1325	2	5	33
Q14	2.2424	2	2	0.8303	37.0268	0.1445	1	5	33
Q15	2.0909	2	2	0.8048	38.4912	0.1401	1	4	33
Q16	3.8485	4	4	0.9395	24.4110	0.1635	1	5	33
Q17	3.9091	4	4	0.7650	19.5698	0.1332	2	5	33
Q18	4.1515	5	5	1.0344	24.9173	0.1801	2	5	33
Q19	3.7273	4	4	0.9445	25.3397	0.1644	2	5	33
Q20	3.0606	3	3	0.9334	30.4968	0.1625	2	5	33
Q21	3.0303	3	3	0.8472	27.9587	0.1475	2	5	33
Q22	3.3333	3	4	0.8539	25.6174	0.1486	2	5	33
Q23	3.6364	4	4	0.6990	19.2232	0.1217	2	5	33
Q24	2.6667	2	2	0.8898	33.3659	0.1549	1	4	33
Q25	2.9697	3	3	0.5855	19.7156	0.1019	2	4	33
Q26	3.3333	4	4	0.9574	28.7228	0.1667	1	5	33
Q27	3.3939	4	4	1.1440	33.7068	0.1991	1	5	33
Q28	2.9091	3	2	1.0713	36.8266	0.1865	1	5	33
Q29	3.7576	4	4	0.9692	25.7938	0.1687	2	5	33
Q30	3.0606	3	3	0.9334	30.4968	0.1625	2	5	33
Q31	3.4545	4	4	0.8693	25.1639	0.1513	2	5	33
Q32	2.7273	3	2	0.8758	32.1131	0.1525	1	4	33
Q33	2.1818	2	2	0.7269	33.3171	0.1265	1	4	33

Wilcoxon Signed Rank test				
Research Hypothesis	H0: μ = 3 against H1: μ > 3		H0: μ = 3 against H1: μ < 3	
R Test Command	wilcox.test(as.numeric(thedata[,i]), mu=3,alternative="greater")		wilcox.test(as.numeric(thedata[,i]), mu=3,alternative="less")	
Questions	**W**	**P**	**W**	**P**
Q8	378.0	7.54E-07	378.0	1
Q9	252.0	0.000566	252.0	0.9995
Q10	279.0	3.88E-05	279.0	1
Q11	299.0	0.000221	299.0	0.9998
Q12	136.0	0.03721	136.0	0.9662
Q13	92.0	0.02635	92.0	0.9772
Q14	35.0	1	35.0	7.15E-05
Q15	21.0	1	21.0	1.11E-05
Q16	360.5	8.80E-05	360.5	1
Q17	315.5	8.24E-06	315.5	1
Q18	361.5	9.06E-06	361.5	1
Q19	348.5	0.000221	348.5	0.9998
Q20	175.0	0.3584	175.0	0.6529
Q21	110.0	0.4256	110.0	0.5907
Q22	171.0	0.01781	171.0	0.9838
Q23	312.0	5.11E-05	312.0	1
Q24	104.0	0.9802	104.0	0.02126
Q25	30.0	0.6375	30.0	0.4008
Q26	260.5	0.02921	260.5	0.9725
Q27	298.0	0.03256	298.0	0.969
Q28	184.0	0.6869	184.0	0.322
Q29	351.0	0.000195	351.0	0.9998
Q30	175.0	0.3584	175.0	0.6529
Q31	308.0	0.003667	308.0	0.9966
Q32	96.0	0.9598	96.0	0.04308
Q33	10.0	1	10.0	1.09E-05