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IMPACT OF RFID ON RETAIL VALUE CHAIN: A MIXED METHOD STUDY

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ABSTRACT

Radio Frequency Identification (RFID) mandates by large retailers and various government agencies have driven a large number of organizations to roll out the technology. Despite these commitments the business case for RFID is far from reality and is still at its infancy. This dissertation work aims at providing realistic perspective on the potentials of RFID taking business processes and value chain activities into account. The research is applied and interdisciplinary in nature and bases itself on inductive reasoning. The dissertation deals with two broad research questions. The first research question focuses on the impact of RFID on retail value chain. The second research question focuses on the factors that influence RFID adoption decision in retail organizations. To answer the research questions a mixed methodological approach that well caters to the exploratory nature of the work is used. First, formal content analysis methodology is used to analyze both academic and trade articles to come up with key issues and concepts that are developed iteratively. The results from the content analysis along with guiding theories act as the input for the Delphi study which is the second methodology that is used. The results help to develop a conceptual framework of the impact of RFID on retail value chain providing deep insights and enhancing the understanding of potential benefits, RFID applicable business processes and value chain activities, and adoption challenges. These relevant issues are classified across different adoption stages in the framework. Drawing on the extant information systems and organizational innovation literature, this dissertation also investigates the salient drivers of emerging RFID adoption

in retail organizations, and develops an RFID adoption decision conceptual framework. According to this framework technological factor relative advantage, environmental factors competitive pressure and catalyst agent, and value chain factor complexity in retail value chain influence RFID adoption decisions in retail.

The findings from this research will provide a theoretical platform for future RFID research work as well as aid in drawing meaningful managerial conclusions. It will allow to better understand what RFID can deliver, what deficiencies companies reveal, what business processes can be improved, and where its application in the value chain is sensible and likely to occur. It will also aid in better understanding the RFID adoption decision process particularly for retail. The dissertation concludes by highlighting both theoretical and practical implications and suggesting directions for future research. Four recommendations have been provided to future adopters drawing from the two conceptual frameworks derived in this dissertation. The derived frameworks are envisioned to be further refined and tested for other industries to test for generalizability.

Key words: RFID, Delphi, Content analysis, Adoption

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Chapter 1

Introduction

This chapter aims to provide the reader with a background on why this dissertation was initiated. It also describes the problem statement, research questions, purpose and rationale for the study, motivation, and the scope of the dissertation.

1.1. Background

While new technologies come and go, organizations still face the dilemma of identifying, adopting, and implementing the "right" solutions for their current and future business needs (Ward and Peppard, 2002). Particularly in times when budgets are tight and proven business cases are essential, decision makers must make informed technology adoption and implementation decisions before making substantial upfront investments (Ward and Peppard, 2002). The technology adoption decision is further complicated by various other forces such as compatibility with business strategy, integration with existing legacy systems and infrastructures, global competition, influences of suppliers, partners, and customers, etc. In a nutshell, today's business decision makers face tremendous pressure not to miss critical business opportunities as well as not to make technology investments that fail to deliver business value and expected benefits (Barua et al., 2004).

1.1.1. The complexity of technology adoption decisions

The adoption and implementation of information systems particularly inter-organizational information systems (IOS) continues to be an interesting research topic. Advances in information and communication technologies provide organizations with a plethora of potential opportunities to increase operational efficiency, reduce costs, and increase business value (Christensen, 2004; Basole and DeMillo, 2006). As technologies become an integral aspect of organizations, decision makers must understand and critically evaluate the forces and factors that shape the adoption and implementation decision. However, this decision is very complex. In today's global and competitive business environment, executives and IT decision makers must make smart and value-justified decisions about their technology investment and strategy (Rouse et al., 2000; Ward and Peppard, 2002). Organizations must carefully assess their current state of technology, determine potential gaps, identify opportunities, evaluate a range of alternative technology options, and select the right solution(s) that can meet their immediate needs and align with their long-term business goals. In many cases, technology adoption decisions are further complicated by competitive pressures, regulatory influences, and customer requirements. Environmental factors often shape the decisions organizations make with respect to their technology investments. The complexity of the technology decision increases even further when the technology under consideration is just emerging and its value is still not very clear (Easton, 2002; Daley, 2005). In this dissertation the complexity of technology adoption in one such case, namely Radio Frequency Identification (RFID) technology specifically for retail organizations is investigated.

1.1.2. Retailing and RFID

The retail industry represents one of the largest industries in the global economy. It is the second largest sector in terms of the number of employees as well as the number of establishments for doing business in the United States (Vargas, 2007). Increasing globalization has increased retailer competition, thus motivating companies to attain better performance (Koh et al., 2006). Sustaining a competitive advantage is the hallmark of today's retailing environment. Retailing is emerging to be a technology intensive industry where the key differentiator between successful and not so successful retailers is 'the area of technology'.

Retailers see RFID technology as one potential means of staying competitive and achieving profitability both in the short as well as in the long term (Wamba et al., 2006). Major retailers in North America, Europe, and Asia acknowledge the significant opportunities in RFID technology. Wal-Mart in US was the first retailer to realize the possible cost savings that could be made possible by using RFID technology in its supply chain and distribution centers. In June 2003, Wal-Mart mandated its top 100 suppliers to use RFID tags on selected pallets and cases beginning January 2005. For Wal-Mart RFID technology provided a 16% reduction in out of stock situation and a 70% drop in the receiving time of new shipments from supplier within a year of receiving tagged products. The vast improvements arose from in-store inventory tracking capabilities provided by RFID technology.

RFID technology is not limited to suppliers and retailers in the US. In Europe, retailers like Tesco, Marks and Spencer, and Metro Group have implemented RFID technology in their supply chain. In 2004 Tesco, the largest retailer in the United Kingdom (UK) started tagging cases of non-food items at its distribution center and tracking them to their retail stores. By April 2006, 40 out of 1400 Tesco stores were equipped with RFID technology. RFID allowed for greater supply chain visibility and simpler processes for its staff resulting in improved product availability, improved service, and reduced prices for its customers (Collins, 2005a). Marks and Spencer, a major UK based retailer of clothing, food, and home products began testing with RFID in 2003. With RFID use, they were more aware of their inventory and it reduced the time it took to record inventory by seven hours per week for a single store. Additionally, constant inventory updates ensured better product availability (Collins, 2005b). The third largest retailer in the world Metro Group began using RFID in its supply chain in November 2004 to track incoming and outgoing shipments. METRO Group is reaping the time savings, labor reductions and inventory benefits from using the technology. RFID technology allowed for a 14% reduction in warehouse labor, an 11 percent improvement in stock availability, and an 18% reduction in lost goods for Metro Group (Intermec, 2007).

In Asia, most retailers expect to obtain benefit from integrating RFID practices across company lines except for China. Chinese retailers expect to use RFID within their company boundaries in transportation and on personal tagging to monitor the work place.

In contrast, Japanese retailers are using RFID tags to monitor and control distribution and sales of women's shoes and apparel in stores (Fish and Wayne, 2007).

According to IDTechEx (2006), the retail sector will comprise 44% of the global RFID market value for systems including tags by the year 2016. On the other hand, according to a recent survey sponsored by NCR (NPN, 2006) only 9% of participating retailers have an RFID implementation timeline as compared to 44% of participating manufacturers. This indicates that the retail sector is not adopting the RFID technology as rapidly as expected.

1.2. Problem statement

Radio frequency identification (RFID) and barcodes are two examples of automatic identification technologies. The adoption of RFID is still at its infancy while barcode is ubiquitous across the retail value chain. Researchers and practitioners have raised concerns regarding the fundamental value of RFID, the distribution of cost and benefits across the value chain, and company-specific differences. According to (Sheffi, 2004), RFID technology is still not out of the fog of innovation, and the benefits of the technology are not clear in terms of the advantages over barcode technology. The expectation now is even bigger since RFID system must demonstrate to be better than barcode technology in terms of value and benefits. There is need to assess the benefits of RFID realistically based on improvement potential rather than the much hyped anecdotal cases. Due to rapidly changing market conditions that is fuelled by ever increasing global competition, high performance expectations by customers, and the presence of evolving technologies (Lin et al., 2002) retail industry is facing serious challenges that requires them to constantly improve. The industry has grown significantly in the last three decades due to technological innovations and the use of advanced supply chain management techniques that combines technologies, process engineering, quality management, and employee involvement (Fiorito et al., 1998; Ko and Kincade, 1997). There is still more need for new technologies to help the retail industry to sustain its vitality to better respond to increasing market pressure and customer demand. The industry is seeing potential in RFID technology as a possible solution to this challenge. However they are not clear about the ways to harness the potential of the technology to maximize its benefits while controlling the risks. Critics who question the fundamental value of RFID point to the fact that there is little practical experience and research that demonstrate the benefits of the technology compared to existing solutions like barcodes. Most of the earlier literature on RFID was hyped anecdotal cases pedaled by vendors or those who had interest in seeing the technology diffuse rapidly (Jones et al., 2005). Research on organizational and business implications of RFID began to increase gradually (Curtin et al., 2007). RFID and its adoption is increasingly a global concern now as retailers and their value chain partners are not always confined to a single region or even country.

Modern retail industry faces a number of critical challenges. The introduction of technologies like barcodes has not eliminated many over-arching issues such as:

1. Out of stock: Out of stock situation is a big problem for the retail industry. According to (Gruen et al., 2002) average out-of stock level for the retail industry is 8.3%. The root causes identified for the out of stock situation are inaccurate

store ordering and forecasting, upstream activities, and inadequate shelf restocking.

2. Inventory inaccuracy: Inaccurate inventory is another problem that leads to huge losses for businesses. According to the case study results with a US based retailer Raman (2000) claimed that there was inaccurate inventory for over 70% of the stock keeping units in the store.

RFID is an example of automatic identification technology which is more advanced than the barcode technology and can address these issues effectively. This dissertation work deals with the usage of RFID technology in the retail value chain and the underlying RFID adoption decision process. The basic idea of RFID technology revolutionizing the way business is conducted today is through RFID tags that uniquely identifies objects. The numbering scheme as proposed by the Auto-ID center used for unique identification is the Electronic Product Code (EPC). The current adoption of RFID is primarily at the case and pallet levels. However item level tagging is where the future is as it will allow extreme visibility. RFID adoption rolled out with large retailers such as Wal-Mart, Tesco, Albertsons, Best Buy, Marks and Spencer, Sears, Home Depot, Metro and government agencies such as DOD (US department of defense) mandating their suppliers to tag their products at a pallet or case level with the objective of streamlining their value chain processes. The widespread use of RFID could automate individual items or cases or pallets of products, as well as reusable assets throughout the value chain. Real-time visibility could be a reality with RFID which was not possible with bar-code technology.

Although businesses are performing pilot tests that in turn has helped to identify the strengths and weaknesses of the technology, they are yet to proceed to a stage where they can actually compare the value chain performance resulting from full-scale RFID implementations. Given the early stage of RFID adoption there is a lot of uncertainty regarding the actual value and return of investments (ROI) of the technology. In other words there is still a large gap between the ideal vision and the current perception of businesses regarding the value of RFID. RFID is a technology that has the potential to yield benefits to firms. However it needs to be investigated on how RFID can bring value to organizations.

This work is an attempt to delve in this area with the objective of generating a business case for RFID with a skeptical eye looking for pitfalls and challenges. This dissertation seeks to improve the practical understanding of the potential benefits of adopting RFID along with other significant issues. This is intended to be achieved by providing a comprehensive discussion of the benefits that RFID can offer, business processes that are positively influenced by the use of RFID, relevant value chain activities that could be improved by RFID usage, the challenges that must be overcome to turn this dream of conducting business in a new way, a reality, and finally critical factors that influence the decision of RFID adoption. The adaptation of Rogers' four stage diffusion model is used to encapsulate the entire research problem and the sub-problems. The benefits or the effects of the RFID technology across the value chains is also investigated in terms of automational (automating operational processes eliminating or reducing manual intervention), informational (improved capabilities to collect, store, process, and disseminate information), and transformational (facilitating process reengineering) effects which are the primary constructs of the theory of business value of IT.

Even if a new technology is known to be a better way of performing certain tasks getting people to collectively agree to adopt the new technology is a challenging task (Rogers, 1995). It is even more complex to get organizations that are linked together through a value chain to adopt an innovation. Although RFID has a special significance in the value chain due to its ability to improve visibility, its adoption has been slower than predicted (Fergusen, 2007). Businesses particularly retailers are keen about knowing which antecedents have a strong impact on RFID adoption. Adoption of emerging technologies with distinct characteristics is still vaguely understood despite extensive adoption and diffusion of innovation research (Rogers, 1995). There have been numerous instances where existing diffusion theory generalizations could not directly be applied (Sharma and Citurs, 2005). Various models have been developed in information systems and inter-organizational system (IOS) adoption literature to identify antecedents that drive adoption decisions. However, an integrative adoption model incorporating factors from various studies with tested predictive power is still needed for any emerging technology.

The real-time data capture capabilities offered by RFID distinguish it from other technologies such as internet and EDI (Curtin et al., 2007). This warrants research around RFID adoption specifically. Also, most of the literature on technology adoption is dominated by studies that have individuals as the unit of analysis. Thus theories such as technology acceptance model (TAM) and perceived characteristics of innovation have been applied (Plouffe et al., 2001). However for an innovation like RFID that is adopted by firms rather than individuals, these theories are not appropriate since they do not take into account key organizational and environmental factors that influence adoption (Gallivan, 2001). Thus theoretical frameworks relevant for studies on organizational adoption of technology are used (Premkumar and Roberts, 1999; Teo et al., 2004). These frameworks have mostly been drawn from the work of (Tornatzky and Fleischer, 1990) who grouped factors influencing organizational adoption of technology into three main contexts – technological, organizational, and environmental. Orlikowski (1993) affirmed these three contexts as being important to adoption of innovations in organizations using grounded theory development approach.

Rogers' theory of innovation diffusion (Rogers, 1995) is one of the most widely applied theories in the prediction of organizational level technology adoption. According to Rogers' theory there are five technological characteristics that are antecedents to any adoption decision. These characteristics are relative advantage, compatibility, complexity, trialability, and observability. He also emphasized on leader characteristics, internal characteristics of organizations, and external characteristics of organizations as the three groups of predictors of adoption predictors.

Technological factors in the TOE framework that is studied in this dissertation research are referred to as innovation characteristics and include relative advantage, compatibility, complexity, and cost (Premkumar and Roberts, 1999; Ranganathan and Jha, 2005; Sharma and Citurs, 2005). Organizational factors include top management support, IT expertise, organizational size, and organizational readiness that are deemed to be influencing the technology adoption process (Orlikowski, 1993; Premkumar and Roberts, 1999; Ranganathan and Jha, 2005; Sharma and Citurs, 2005; Asif and

Madviwalla, 2005). Finally, environmental factors refer to the role of external environment in the technology adoption process. These factors include competitive pressure, external support level, and the existence of change agents (Premkumar and Roberts, 1999; Ranganathan and Jha, 2005; Sharma and Citurs, 2005). The adaptation of the TOE framework is used to study the RFID adoption process in this dissertation.

The technological characteristics identified by Rogers clearly relate to the technological context. The leader characteristic can be viewed as organizational and the external characteristics refer to the environmental context of the TOE framework. Thus we can say that Rogers' theory of innovation diffusion is consistent with the TOE framework (Zhu et al., 2006a; Zhu et al., 2006b).

To summarize, this dissertation provides an improved understanding of the potential of RFID technology and the RFID adoption decision making process in retail organizations. Key RFID adoption factors that influence technology adoption decision making process at the firm level are identified and discussed. The RFID adoption process in light of the potential benefits and values of the technology situated in the context of specific business processes and value chain activities will be of value for researchers and practitioners. The dissertation thus intends to spread the knowledge about RFID technology, its potentials and challenges, and the critical factors influencing the RFID adoption decision making process. This is an area that is currently under-researched and deserves much needed attention and is thus of immense practical considerations.

1.3. Research questions

Analyzing the potential effects of RFID on retail value chain is of high practical as well as scientific significance. Analyzing the value and benefits will not be complete without understanding the critical factors that influence the RFID adoption decisions. This dissertation aims to improve the understanding of the value of RFID and the adoption process for retailers by addressing the following research questions. Primary reason for choosing retail industry as the research object is retailers' association with the value chain. Typically retail industry does not function stand alone and is heavily dependent on its value chain partners. Since RFID could significantly impact the value chain operations for retail sector we can see business case for RFID adoption.

The scope of this dissertation is to understand and investigate the impact of RFID specifically for the retail end of the value chain. The impact of the technology on other entities across the value chains are envisioned as future research problems. The rationale for this is to go in-depth into the retail end of the value chain.

A conceptual value chain perspective is used to study the retail value chain where the value chain is considered as a whole system. From this perspective this research focuses on the interaction of the retail entity with other value chain partners starting from the product filling point at the manufacturer's end where the product is merged with the primary packaging, via distribution centers, and eventually to the point of sales at the retail outlets, where the products are sold to end consumers. Figure 1-1 shows the value chain perspective that is used in this research. The two broad research questions that this dissertation investigates are as follows:

Research Question (R.Q) 1: What is the impact of RFID on retail value chain?

In order to address the borad research question, the following sub-questions are considered:

R.Q.1.1: What are the key benefits of RFID adoption for retail end of the value chain?

R.Q.1.1.1: Are these benefits automational, informational, or transformational in nature?

R.Q.1.2: Which retail business processes are influenced by RFID?

R.Q.1.3: Which retail value chain activities are influenced by RFID?

R.Q.1.4: What are the key challenges of RFID adoption for retail end of the value chain?

R.Q.1.4.1: Are these challenges technological, organizational, or environmental in nature?

Research Question (R.Q) 2: What are the determinants of retail adoption of RFID technology?

R.Q.2.1: Can the set of antecedents: relative advantage, cost, complexity, compatibility, top management support, organizational size, IT expertise, competitive pressure, external support, catalyst agent, value chain information intensity, and value chain complexity predict the adoption of RFID in retail organizations?

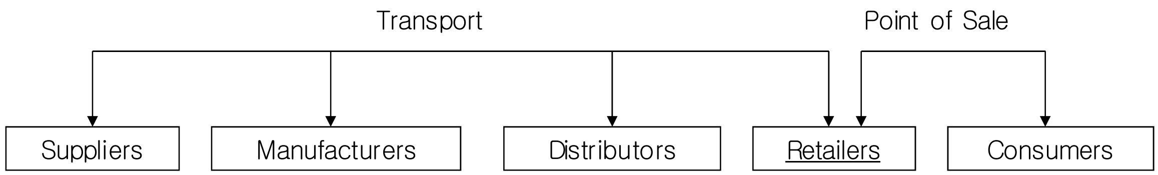

Figure 1-1: Retail value chain

1.4. Purpose of the study

The purpose of this dissertation work is manifold. The most important objectives to be accomplished are as follows:

1. To identify existing work regarding impact of RFID throughout the literature to create a succinct list of previously identified potentials and concerns and to evaluate the extent to which these known issues arise in the literature.
2. To critically analyze these results through frequency analysis and narrative analysis of those analyses.
3. To identify and critically analyze determinants of RFID adoption decision in retail organization.
4. To develop conceptual frameworks on RFID impact and adoption resulting from a comprehensive content analysis of the existing literature and data collected from Delphi technique that will guide future research and enable drawing meaningful insights.

1.5. Rationale for the study

The rationale for conducting this study originates both from the practical and scientific concerns. From a practical standpoint RFID in general is a topic that deems investigation considering the ever-increasing interest in the technology in current times be it due to the mandates from large retailers and government agencies or due to the potentials benefits that it can create upon usage. It is a topic that is creating current debate throughout the business and academic world. A lot of companies are still in the early stages of adopting RFID and there seems to be a lack of knowledge on the actual value of the technology and how it is likely to affect their operational and value chain processes. An indicator in support of this argument is the increasing number of conferences and special issues of journals on various topics of RFID. This dissertation seeks to make an attempt to improve the practical understanding of the potential benefits of RFID and other overarching issues that directly or indirectly influence those benefits along with improved understanding of the determinants of RFID adoption in retail.

Also, there is limited academic research that deals with the impact of RFID on business process performance. There is abundant literature on the technology behind the devices, the encryption methods, and the endless possibilities with the technology. However, there is substantially less literature on the impact of the technology on operational and business processes. Some of these articles are in-depth and give a very good explanation of the issue, but most are concerned about a single aspect. Other articles that refer more than one issue do so very briefly. Throughout the literature, there is a constant gap that is apparent. Many articles have been written on the topic; however they have either done it very briefly or have delved deep into a single issue. No author has yet taken the vital step of linking together important issues raised by the prevailing articles in order to provide a comprehensive narrative discussion of the relevant issues that in turn can clarify many of the inherent uncertainties associated with the technology. To the best of my knowledge there are no studies that discussed a comprehensive content analysis on the topic of the impact of the RFID technology on operational and business processes for retail industries. Also RFID being an emerging technology it is extremely important to understand the RFID technology adoption process. It can be achieved by indentifying the determinants that influence the RFID adoption decisions particularly in retail organizations. This dissertation thus intends to fill the gap in the literature and open new avenues of research in this area. The main argument for exploring this research at this point in time is the high practical relevance of the topic.

1.6. Motivation

The motivation for this dissertation derives from the practical challenge of a lack of understanding on how and why RFID technology can be applied by the industries. A thorough understanding of the potential benefits and limitations of the technology is a necessary step before wide spread RFID adoption by companies will turn into a reality. Also it is important to identify the determinants that influence the adoption process. Additionally this dissertation aims to provide a theoretical framework that applied researchers may use to get a better understanding of the value of the RFID technology in different contexts and thereby improve the quality of their recommendations to companies.

1.7. Scope and delimitations of the dissertation

This dissertation specifically studies the impact of RFID on the retail end of the value chain with respect to operational and value chain processes. The focus is retail end of the value chain. Retail industries hugely depend on the effectiveness of the value chain that could be dramatically be streamlined by implementing RFID. The impact of RFID on entities other than retail end of the value chain is beyond the scope of this dissertation. The unit of analysis in this research work is the impact of the RFID technology on the value chain in terms of the different issues under consideration with organizational level of analysis. RFID technology is considered from a business perspective rather than a consumer perspective. The focus is on the flow of finished products or parts and information in the value chain through upstream and downstream linkages in different processes and activities that produce value in the form of finished goods and services in the hands of the consumer. The primary reason for choosing retail industry as a research object is that retailers have a lot of experience with the barcode technology. This allows observing the incremental advantages of RFID over barcodes which is another means of automatic identification. Additionally there is a focus on value chain management in retail industries that allow the investigation of the potential impact of RFID in value chain management. Finally, retail industries are big proponents of RFID technology that contributes to data availability and thus provides the means to conduct this research. So the decision for choosing retail industries as research objects is somewhat opportunistic as well.

1.8. Dissertation outline

This section provides an overview of the structure of this dissertation. The dissertation is organized as follows:

1. Chapter 1: Introduction

This chapter aims to explain why this dissertation work was carried out, its purpose, motivation, scope and delimitations as well as introduce the research questions that are studied.

2. Chapter 2: Literature review

In this chapter the theories that are important for analyzing and understanding the areas of investigation are presented. It also lays out a detailed discussion of RFID studies that serve as the motivation for this research.

3. Chapter 3: Research design and methodology

This chapter provides the reader with information about how this dissertation was carried out. The overall research approach as well as process used throughout this dissertation is presented. It also includes a discussion about the data collection techniques and the validity and reliability of the study.

4. Chapter 4: Data analysis and discussion: A conceptual framework of the impact of RFID

This chapter derives a conceptual framework of the impact of RFID from the combined results of content analysis and Delphi study. It aims to put the findings into a theoretical perspective.

5. Chapter 5: Data analysis and discussion: A conceptual framework on RFID adoption

This chapter derives a conceptual framework of RFID adoption based on Tortantzky and Fleischer's (1990) technology-organization-environment (TOE) framework. TOE framework is tested and extended for RFID technology adoption in retail.

6. Chapter 6: Conclusions and contribution

This chapter contains a summary of the key findings, presents the theoretical, industrial, and academic contributions along with research limitations, and introduces future research directions.

Chapter 2

Literature Review

This chapter aims to provide a background on the theoretical foundation and the review of related work that serve as the motivation and the base for this dissertation work.

2.1. Theoretical foundation

Past research on advanced technologies suggests that the outcomes of a technology depend more on how it is used by people than the technology itself (DeSanctis and Poole, 1994). Thus the layout of the dissertation incorporates five distinct patterns that are adoption determinants, benefits, value chain activities, business processes, and challenges. Three main theoretical perspectives will be used as foundation in this dissertation work to investigate the impact of RFID in retail value chain and the adoption process. The first theory is Rogers' theory of diffusion of innovation; the second one is the technology-organization-environment (TOE) framework; and the third one is the theory of business value of information technology (IT).

2.1.1. Roger's theory of diffusion of innovation

Diffusion is the process by which an innovation that could be a new technology communicates through certain channels over time among the members of society. The diffusion of innovation is considered to be the first theory about innovation acceptance. Everett Rogers formalized the theory in his book *Diffusion of Innovation* (1995). Rogers categorizes system member innovativeness into five categories where innovativeness defines the degree to which a member is relatively earlier in adopting new innovation than other members. These categories are: innovators, early adopters, early majority, late majority, and laggards. Innovators are thought to be up to date with cutting edge technologies and have the ability to gain information from multiple sources as well as having the nature to take risks. Early adopters are deliberate members with many informal social contacts that use the data provided by the innovators to make their individual adoption decisions. Early majority are members who deliberate for sometime before completely adopting a new idea. They adopt new ideas just before the average member of a system. Late majority is classified as the skeptics and traditionalists and conforms to the opinion leaders decision but a little late because of uncertainties. Finally, laggards are classified as those who are either very traditional or are isolated from the social system and take much longer than average to adopt new innovations.

Rogers proposed a five-stage model of innovation adoption and implementation in enterprises. He defined the adoption process as "the process through which an adopter unit passes first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision." In particular, Rogers (1995) argued that the decision to adopt and use unfolds in the following five stages that are interlinked with each other. These stages are:

1. *Knowledge:* In this stage, a member becomes aware of the existence and uses of an innovation.
2. *Persuasion:* In this stage, a member forms a favorable or unfavorable attitude toward the innovation.
3. *Decision:* In this stage, a member engages in activities that lead to making a choice of adopting or rejecting the innovation.
4. *Implementation*: In this stage, a member actually begins using the innovation.
5. *Confirmation:* Finally, this stage determines whether the member accepts or rejects the innovation.

In his theory of innovation diffusion Rogers also proposed (Rogers, 1995) five technological attributes that regularly determine the adoption of innovations. He defined them as follows:

1. Relative Advantage: It refers to the degree to which an innovation is perceived as being better than its precursor. The degree of relative advantage may be measured in economic terms, but intangible aspects such as convenience and satisfaction are also important factors. The greater the perceived relative advantage of an innovation, the more rapid its rate of adoption will be.

2. Compatibility: It is the degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters. An idea that is incompatible with existing values and norms of a social system will not be adopted as rapidly as an innovation that is compatible.
3. Complexity: It is the degree to which an innovation is perceived as difficult to understand and use. Some innovations are readily understood by most members of a social system; others are more complicated and will be adopted more slowly. New ideas that are simpler to understand are adopted more rapidly than innovations that require the adopter to develop new skills and understandings.
4. Observability: It is 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 it.
5. Trialability: It is the degree to which an innovation may be experimented with before adoption. An innovation that is trialable represents less uncertainty to the individual who is considering it for adoption and can learn by doing.

These five attributes have been extensively utilized by many researchers to explain the adoption and diffusion of innovations. However, among these attributes, only relative advantage, compatibility, and complexity have been consistently identified as critical technology adoption factors (Kwon & Zmud, 1987).

Along with the five technological characteristics, Rogers also emphasized three groups of adoption predictors that are leader characteristics, internal characteristics of organizations, and external characteristics of organizations. They are consistent with the constructs of the TOE framework (Zhu et al., 2006a; Zhu et al., 2006b).

Rogers' innovation diffusion stage model is adapted in this dissertation research to encapsulate the research problem in order to develop a basic RFID impact framework specifically for retail sector. The idea is to extend Rogers' model specifically into the context of RFID adoption that will potentially serve as a framework for future research works to study the impact of RFID and other automatic identification technologies in general.

2.1.2. Technology-organization-environment (TOE) framework

While certain organizational factors along with perceived organizational benefits often enable technology adoption, the absence of enablers can present themselves as inhibitors of adoption. According to the stream of research on organizational technology adoption *technological, organizational, and environmental* factors are identified to be most relevant to the adoption of technologies in general and could be applicable to the RFID technology adoption as well.

(Tornatzky and Klein, 1982) examined the relationship between technological or innovation characteristics and adoption. The 10 characteristics that were found to be most frequently used were relative advantage, complexity, communicability, divisibility, cost, profitability, compatibility, social approval, trialability, and observability. Out of these 10 characteristics, relative advantage, complexity, compatibility, and cost were found to be consistently related to adoption studies. Recent IT adoption studies have also found these variables to be important in the context of adoption of various information technologies (Cooper and Zmud, 1990). One of the first challenges that can be identified in RFID or any new technology adoption is the cost of the physical implementation with regards to hardware and software. Adoption of such infrastructure is of significant cost to the organization. However such technologies also bring cost savings that implementing the technology might bring to an organization which corresponds to the relative advantage of the new technology compared to its predecessor technologies. The issue of complexity can refer to both the complexity of the technology implementation and the technology itself (Gallivan, 2001). Compatibility refers to the deviation from previous ideas, values, or technologies that the new technology supersedes.

The literature on organizational innovativeness explored the influence of organizational characteristics on adoption decisions (Damanpour, 1991). This perspective emerged as researchers recognized that decisions at the firm level are often too complex to be captured only by an individual's cognitive abilities (Tornatzky and Klein, 1982) and could not be directly addressed with traditional technology adoption and diffusion models (Rogers, 1995).

Organizational factors identified in IT adoption studies are top management support, organizational size, existence of product champions, and availability of resources. Top management attitude and support ensures availability of adequate resources for implementing the innovation (Grover and Goslar, 1993). Studies suggest that providing sufficient resources and creating conducive environment for innovation adoption within an organization comes from the top management and is positively related to innovation adoption and diffusion process (Rogers, 1995; Premkumar and Roberts, 1999). The availability of organizational resources, such as financial, human, and physical was shown to be of significant importance in the adoption decision and implementation success (Depietro et al., 1990). Organizational size has repeatedly been found to influence innovation adoption (Gremillion, 1984).

Also, organizations must be willing to make changes in business processes for benefits to accrue (Kinsella, 2003; Brown and Russell, 2007). Moreover there must be a cultural willingness to move beyond conventional methods and to take risks to ensure innovation adoption (Hoske, 2004).

Organizational innovativeness studies have provided a number of additional determinants that influence adoption of information technologies. However this stream of research assumes that organizational adoption of information technologies is driven by intra-organizational factors that are independent of environmental context (Zhu et al., 2002). Organizational behavior and strategic management studies, however, provided evidence that organizational technology adoption decision-making was also influenced by contextual environmental factors. This shortcoming of enterprise adoption models led to the examination and integration of environmental factors in enterprise adoption research.

Competitive pressures, vendor influence, and regulatory forces are all environmental factors that could impact an organization’s decision to adopt an innovation. Thus, an understanding of the institutional environment in which businesses operate is extremely important. Factors that are external to an organization but influencing its functioning and decision making e.g. governmental push, technology standards development, legal environment, consumer readiness with increasing awareness, technological breakthroughs etc. have been characterized as environmental factors. (Tornatzky and Fleischer, 1990) identified competitive pressure, governmental regulations, and consumer readiness as environmental factors influencing innovation adoption.

The TOE framework is widely accepted since findings from innovation adoption studies are empirically supported and thus consistent with it (Cooper and Zmud, 1990; Thong, 1999). The framework has been used to study adoption of general IT innovation (Chau and Tam, 1997; Zhu et al., 2006a; Zhu et al., 2006b) as well as specific IT innovation such as EDI (Kuan and Chau, 2001).

The TOE framework is adapted to make it particularly suitable to study RFID adoption process in retail organizations in this dissertation. The goal is to develop a comprehensive RFID adoption conceptual framework. Based on the multiple theories perspective of TOE framework to explain enterprise adoption, there is also an opportunity to develop a single, integrated model that will provide a holistic view on the factors involved in this complex decision. Also, despite the plethora of enterprise adoption studies, only a very small percentage has examined disruptive organizational technologies like RFID. Given the growing importance of RFID technology it is thus critical to examine whether existing models apply, and if not, how they can be modified or extended.

2.1.3. Business value of information technology (IT)

Researchers suggest that information technology (IT) creates business value along three dimensions that lead to automational, informational, and transformational effects (Mooney et al., 1996; Dedrick et al., 2003). These effects are briefly discussed below:

1. Automational: This effect enhances efficiency by automating operational processes that need manual interventions and are subject to errors.
2. Informational: This effect leads to increased performance by achieving improved capabilities to collect, store, process, and disseminate information which can lead to better decisions and thus improved quality.
3. Transformational: This effect refers to the role of IT in facilitating process reengineering and redesigning organizational structures (Mooney et al., 1996).

As an example in the context of RFID technology, the technology can eliminate time for manual counting of number of cases, pallets, or cases on a pallet (automational effect), reduce the number of shipping errors (informational), and change manual replenishment process of stock from backroom inventory to shop floor (transformational).

In this dissertation work the three dimensional effects of IT is used to investigate if it applies to automatic identification technologies like RFID. The goal is to apply this theory for studying the impact of RFID and to put the findings into a theoretical perspective that could apply for other auto-ID technologies as well. Table 2-1 provides a list of the three theoretical perspectives used in this dissertation research, their core constructs used, and contribution to this dissertation.

Table 2-1. Contributions of theories in dissertation

Theories	Core Constructs used in Dissertation	Contribution to Dissertation
Rogers diffusion of innovation	Innovation characteristics Stage model of adoption	Encapsulate research problem Development of RFID impact model
Technology-organization-environment framework	Technological context Organizational context Environmental context	Development of RFID adoption model
Business value of IT	Automational Informational Transformational	Better understanding of the dimensions of RFID potential benefits

In order to achieve the objectives of this research, RFID specific technical literature along with the literature related to the use of RFID in supply chain management consisting of both empirical and analytical/simulation studies and RFID adoption studies provide the basic frame of reference that must be considered. The most relevant articles are included to build the theoretical frame of reference for this study.

2.1.4. RFID: Technical overview

RFID refers to an automatic identification technology that uniquely identifies items and gathers data on those items without the need for human intervention (Wyld, 2006). It is a wireless technology that allows transmission of information without requiring physical connection or line of sight unlike other automatic identification technologies like bar-codes (Karkkainen and Holmstrom, 2002). Although the commercial application of RFID in supply chain management is new, the technology itself dates back to the World War II days and was developed for detecting enemy aircrafts (EPCGlobal, 2004). The first commercial applications appeared in the 1960s in the form of electronic surveillance systems, followed by applications in animal tracking and payment on toll roads in the 1980s (AIM, 2001; Jacob et al., 2004; Capone et al., 2004; RFID Survival, 2003). With technological advancements and cost reduction, RFID has become an important solution for automatic identification in supply chain operations over the last decade.

A typical RFID system that is used in supply chain operations has four elements: Electronic product code (EPC), tags or transponder, reader or interrogator, and a computer equipped with a middleware application that manages the RFID equipment, filters data and interacts with backend enterprise applications (Asif and Mandviwalla, 2005; Hodges and Harrison, 2003). Figure 2-1 shows the components of an RFID system.

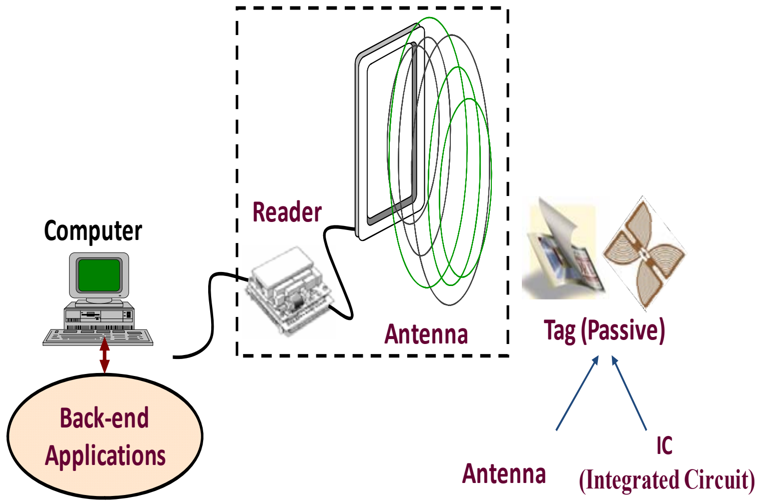

Figure 2-1. Components of an RFID system

Electronic product code (EPC) is a unique identification number assigned to an item or product that moves along the supply chain (EPCGlobal, 2004). The concept of the EPC allows for unique identification on all levels of implementation such as pallet, case, or item. It consists of several partitions which uniquely identifies the version, the producer called EPC manager, the object class, and the serial number of the item that is tagged. A tag or transponder which is attached to the item consists of a microchip that stores identification data of the item and an antenna that transmits the data to the reader via radio waves when it moves through the electromagnetic zone of the reader (Finkenzeller, 2003). A reader also called an interrogator sends out radio signals to prompt the tag to broadcast the data stored on its chip. The reader captures the radio waves emitted by the tag and converts them into digital data and passes to the external world through reader interface layer called middleware. The middleware controls the RFID system, compresses thousands of tag signals that the reader captures into a single identification, and acts as a conduit between RFID hardware elements and backend enterprise applications like Manufacturing Execution systems (MES), Supply Chain Management (SCM) system, and Enterprise Resource Planning (ERP) system (Chang et al., 2002).

RFID systems can be classified according to the frequency and power supply of the tags. The frequency of a RFID system refers to the operating frequency of the reader and is a key determinant of the performance level of the system. The frequency determines the reading range of the RFID system. The frequencies that are used in RFID systems are low frequency (LF: 125-134 KHz), high frequency (HF: 13.56 MHz), ultra-high frequency (UHF: 868-956 MHz), and microwave frequency (MF: above 1 GHz) (Datta, 2005).

Low frequency waves are the typical waves that reach our radio and they can penetrate RF (Radio Frequency) lucent materials. However low frequency waves have difficulty penetrating metals. Thus, low frequency systems are useful for applications requiring close range reading through RF lucent materials or liquid/water. High frequency systems operate more like light waves, greatly reducing their effects near metals and liquids, and limiting their ability to penetrate metals. High frequency tags can be read up to three feet in range (RFID Journal, 2006). Ultra high frequency systems have read ranges greater than ten feet (between 10-15 feet). These systems also experience difficulties with metal and water since UHF waves are absorbed by water and reflected by metals (RFID Journal, 2006).

Another determinant of RFID system characteristics is the tag type based on the method by which the tag receives its power supply. The three main classifications of the tag types are passive, active, and semi-passive (Wyld, 2005). Passive tags receive the power from the RF signal sent from the reader or the magnetic field emitted from the reader's antenna; they do not have their own power source. Active tags on the other hand contain their own power source in the form of battery. They usually have longer reading range and are more expensive than in comparison to passive tags. Semi-passive tags have a power source for the microprocessor but the data transmission is powered by the reader.

Use of passive tags operating under UHF band is the most dominant choice for supply chain application because of lower cost and adequate read range. Any item such as container, pallet, case, or product may be RFID-tagged. Tagging level depends on the desired information needed as well as value and cost of the item (McCrea, 2004).

Placement of tags on an item is very crucial for an effective RFID solution. Generally, a vertical tag orientation is best for optimal readability. Also tags should be placed on the side of the item to ensure longer life span of the tags. In the context of supply chain management, the product information that an RFID system captures consists of instance data (dates of manufacturing and expiration), history data (departure and arrival dates and time), product category data (description, dimensions, and selling units, and commercial entity data (address and telephone number) (EPCGlobal, 2004). Thus an RFID tag actually evolves throughout the supply chain, containing more accurate and detailed information making the product somehow intelligent (Agarwal, 2001).

2.1.5. RFID: Supply chain management

A supply chain incorporates all processes involved in transferring materials and subsequent information from the starting to the end point. According to (Markland et al., 1995) a supply chain is the connected series of value based activities that is concerned with planning, coordinating, and controlling of materials, parts and finished products from suppliers to the final customers. Communication flow throughout the supply chain is extremely important to achieve overall efficiency and the way to achieve it is through integration of all supply chain entities. Coordination of activities across the supply chain adds value for the customer as well as increase profitability of every entity in the chain (Anderson et al., 1997). Adding value to the traditional supply chain results in an innovative and improved model described as a value-based chain. A value based chain is more complex and relationship-oriented than the traditional linear supply chain model. It views components holistically and focuses on increased communication throughout the chain. The value-based chain incorporates enhanced collaboration among entities, increased information technology, and more personalized service for customers.

Increased value in the supply chain leads to competitive advantage for businesses. Although there are various ways of viewing the supply chain, the basic structure relating to the flow of products is similar for every industry.

The key stages involved in the movement of goods and information include acquisition of raw materials from suppliers, manufacturing of final products from the raw materials, distribution of final products to retailers, and finally point of sale interaction with the customers. Related to these processes are various activities specific to each function. Managing the supply chain is crucial, considering that nearly $3.4 trillion dollars are spent on supply chain operations globally and much of this cost is wasted because of poor supply chain integration resulting in an inefficient supply chain (Nelson, 2001).

Information is vital to the success of the entire supply chain. Information provided from one entity within the supply chain to the other is the factor that differentiates the value-based supply chain from the traditional linear approach (Markland et al., 1995). Sharing of information among supply chain entities leading to the integration of the chain eliminates the amount of guess-work involved in decision making (Burnell, 1999). Improved information sharing across an integrated supply chain can result in reduced inventory, improved productivity, and improved customer service levels thus providing competitive advantage to the businesses (Trebilcock, 2000). The knowledge that improved information sharing leads to competitive advantage has caused businesses to invest more and more on enabling information technologies like bar-codes and RFID and supporting technologies that process the collected data into valuable information.

RFID being a superior technology than in comparison to bar-codes that does not need line of sight thus allowing real-time visibility across the supply chain is the most recent technology innovation for improving efficiency across the entire supply chain. RFID when used in supply chain management can create and sustain a firm competitive advantage (Tajima, 2007). Many supply chain processes can be enhanced using RFID technology. It can be implemented into a variety of activities starting from the receipt of raw materials to the delivery of products to customers in order to provide competitive advantage. Due to the considerably high cost of the RFID technology it can be very expensive to apply the technology to each step in the supply chain. Therefore the major challenge is to investigate individual company practices and determine the processes and activities that will benefit the most from it so that the implementation is opportunistic.

In the past few years, RFID technology has been expanding into the areas of tracking video cassettes in rental stores for better inventory management, tracking meat throughout processing facilities to monitor temperatures, and tracking reusable containers as they are transferred between suppliers and manufacturers. The success of these applications has inspired industries to expand the technology across new horizons to better integrate the supply chain so that they are transformed into intelligent, self managing entities (Schmidt, 2001).

The advantage that RFID is expected to provide over bar codes include faster information retrieval, improved supply chain visibility, higher information content, and less probability of loss or theft (Hickey, 1999; Sellito et al., 2007; Kumar et al., 2009). Improved supply chain visibility and full or semi automation of rote operations are significant benefits that could be achieved from RFID technology implementation (Bose and Pal, 2005). Reducing the costs associated with lost products can lead to huge savings for companies that implement the technology (Roberti, 2002). Another benefit that RFID can provide when implemented within a supply chain is reduced shrinkage from employee or customer theft, vendor fraud or errors (Roberti, 2002) by providing real-time information about the movement of goods and alerting security systems when unauthorized product movement is encountered. The other area that could be significantly improved by using RFID technology is reduced out of stocks (Bhattacharya et al., 2007; 2008; 2009; 2010; Karkkainen and Holmstrom, 2002; Karkkainen, 2003).

RFID can provide real-time information on product movement which could be utilized for accurate forecasting thus resulting in reduced out-of-stock situations. The technology leads to savings that comes from improved inventory management, reduced employee errors, replenishment productivity, and reduced stock loss (Karkkainen, 2003). From comprehensive content analysis study Bhattacharya et al., (2007; 2008; 2009; 2010) suggests that better inventory management, and improved security are the most significant benefits that RFID provides to retailers. They also identified significant RFID applicable retail specific tasks and relevant value chain activities. Among the most significant applicable tasks, inventory management and tracking and tracing are important for both retailers and manufacturers. And finally among the value chain activities, the most significant activities for retailers are replenishment, warehouse management, in-store operations, and returns. Angeles (2005) claimed that RFID can enable real-time visibility into supply chains and also ensure process freedom of two primary business processes that includes distribution (that incorporates: receiving, check-in, replenishment, order-filling, and shipping) (Karkkainen, 2003) and transportation (that incorporates product and asset tracking) from manual interventions thus reducing the chances of errors.

RFID provides real-time visibility thus leading to a better integrated supply chain with better and timely information flow, improved returns management, improved anti-theft capabilities, and improved customer service level for retailers (Jones et al., 2004).

Benefits are achieved by companies using RFID in their processes in different supply chain phases of sourcing and production, distribution, retail, and after-sales services. RFID allows for more efficient goods receipt and flexible mass production within sourcing and production phase; greater speed and accuracy, reduced labor requirements, and improved services within warehousing and distribution phase; and finally it eliminates check-out costs, reduces out of stock, and allows for effective asset management within the retail and after-sales phase of the supply chain (Karkkainen and Holmstrom, 2002). Within grocery retailing RFID allows for automated inventory replenishment, improved customer service, reduced stock out situations, and improved information sharing thus leading to a more controlled supply chain resulting from the improved visibility (Prater, 2005).

Since RFID allows for individual item tracking and more detailed data capture than barcodes, it can synchronize the flow of data with products through the chain thus allowing for improved timeliness, accuracy, and granularity of data for all supply chain partners (Johnson, 2005). (Ranky, 2006) suggests that RFID improves tracking and tracing of products and assets across the supply chain for major manufacturers, distributors, and retailers thus leading to a tighter supply chain and enhanced customer service levels.

Within the pharmaceutical industry RFID has huge opportunities. It promotes security, safety, and efficiency of the pharmaceutical industry by preventing counterfeit drugs from entering the drug supply chain and in controlling the pharmaceutical stocks in the retail supply chain, healthcare facilities, and in the supplies of sample drugs (Wyld and Jones, 2007). They also suggest that the track and trace capabilities of RFID would facilitate product recalls, allowing for drug supply chain members to quickly locate counterfeit drugs. The technology further enables smart shelves that manage the drug stock and automate the replenishment process, and also records unusual activities in the supplies thus preventing theft or unauthorized access to controlled substances.

Future challenges that need to be overcome for wider RFID technology adoption are privacy, massive data management, high cost, and technical reliability issues (Metras, 2005; Want, 2006; Jones et al., 2004; Vijayaraman and Osyk, 2006; Lin et al., 2006; Cooke, 2005; Kapoor et al., 2009; Moon and Ngai, 2008; Smart et al., 2010). Also disputes regarding the cost and benefit sharing, lack of standards, system integration issues, business process reengineering requirements, and the need for work force transformation because RFID forces new business practices will remain challenges inhibiting RFID adoption (Karkkainen and Holmstrom, 2002; Ranky 2006; Bhattacharya et al., 2007; 2008; 2009; 2010).

2.1.6. RFID: Empirical and analytical studies

In this section some of the key academic RFID adoption studies are reported. These studies are both the motivation as well as the foundation of this dissertation work. Most of the empirical studies deal with the realistic value of RFID.

One group of the empirical studies use surveys and structured/semi-structured interviews to find out the perceptions of industry and academic experts and consumers on RFID (Juban and Wyld, 2004; Knebel et al., 2006; Koh et al., 2006; Kumar et al., 2007; Lin et al., 2006; Smith, 2005; Vijayaraman and Osyk, 2006).

Another group uses case study approach to investigate value of RFID (Delen et al., 2007; Wamba et al., 2006; 2008; Srivastava, 2007; Karkkainen, 2003; Moon and Ngai, 2008).

A third group of analytical studies used mathematical models to compare across operations before and after RFID implementations in order to estimate the value of RFID from the difference in performance measures (Jarugumilli and Grasman, 2007; Lee and Ozer, 2007; Wu and Chen, 2007; Lee et al., 2004; Gaukler et al., 2007; Jurishica and Schwieters, 2004; Sarac and Saint-Etienne, 2008; Wang et al., 2008). They assumed some simplified conditions of the actual situations.

Based on the results of the empirical and analytical studies, the potential benefits of RFID include improved visibility, improved inventory management, increased speed and accuracy in operations, improved cost savings, improved customer satisfaction, greater quality assurance of products, improved recall management, and reduction of various measures that include errors and losses, labor requirements, theft, safety stocks, and shrinkage.

The key challenges for RFID adoption that are identified include privacy concerns, integration issues, performance and reliability issues, high cost, uncertain return on investment (ROI), data management issues, standard issues, and unequal cost/benefit sharing.

The business processes that are improved with RFID across a specific supply chain are identified to be receiving and put-away, picking, shipping, and replenishment. Optimization of these processes can be achieved when RFID is used by eliminating or reducing manual interventions that is otherwise needed thus contributing to cost savings.

RFID aids in the development of new smart business processes triggered by automated events e.g. as soon as a truck leaves the manufacturing facility, an ASN (Advanced Shipping Notice) is sent to the distribution centre via the EPC (Electronic Product Code) and also allowing transit visibility through GPS (Geographical Positioning System) tracking between the manufacturer and the distributor. RFID also allows merging of both intra and inter-organizational business processes. As an example of intra-organizational process integration, receiving and put-away processes could be merged by RFID by automatically linking in-coming product information to dedicated shelves in the warehouse thus reducing the need for staging areas. As an example of inter-organizational process integration, the shipping process at the manufacturer end could be integrated with the receiving process at the retailers' end by linking incoming physical and digital RFID tag products to digital information (ASN) received through EPC network from the manufacturer.

A major issue for those interested in the application of RFID technology is the lack of empirical research published in reputed scientific journals and conference proceedings. Academic research has thus both an opportunity and responsibility to participate in empirical investigation of RFID adoption and provide unbiased information to users. This provides the motivation to conduct empirical research on this topic. RFID adoption being a new area, the scenario is constantly changing and needs lot more research.

2.1.7. RFID: Technology adoption

Most prior studies on RFID adoption have focused narrowly on a few factors influencing the adoption decision rather than all the three important factors revolving around technological, organizational, and environmental contexts. In this section RFID adoption studies that focused on more than one of these three important factors influencing the organizational adoption of RFID technology is discussed.

(Wang et al., 2010) conducted a study to understand the determinants of RFID adoption in the manufacturing industry. They found that technological, organizational, and environmental contexts determine whether a firm adopts RFID technology. Specifically they concluded that information intensity, complexity, compatibility, firm size, competitive pressure, and trading partner pressure significantly determine RFID adoption. Among these six determinants information intensity and complexity negatively influence RFID adoption whereas the remaining four factors positively influence the adoption decision.

(Wamba et al., 2009) identified 21 important factors put in four categories that were related to the decision to invest in RFID technology. The four categories of factors influencing RFID adoption decisions are technology, automation, resource, and supply chain. The four categories are consistent with the constructs of the TOE framework.

(Madlberger, 2009) developed a model of antecedents of RFID adoption intention in supply chain. This study incorporates an economic perspective to investigate the antecedents of RFID adoption. The results indicate that perceived internal and inter-organizational benefits as well as future costs of RFID implementation are significant in predicting organizational adoption intention. Firm size, and applied technologies showed no influence on RFID adoption intention.

(Wen et al., 2009) conducted a study of the determinant factors of RFID adoption by manufacturing companies in China. The study revealed that environment, organization, environment, and product factors have an impact on the adoption of RFID in China. They suggested that organizations should give strategic attention to improve employee participation in adopting RFID as a business tool.

(Leimeister et al., 2009) performed a cross-national comparison of perceived strategic importance of RFID for CIOs (Chief Information Officer) in Germany and Italy and found that perceived potential benefits of RFID influence perceived strategic importance which positively influences CIO's intent to invest on RFID technology.

Another study conducted by (Pedroso et al., 2009) identified that organization and motivation factors determine RFID adoption decisions in large Brazilian companies.

(Lin and Ho, 2009) performed an empirical study on RFID technology adoption in China's logistics industry and found that adoption decisions are influenced by the explicitness and accumulation of technology, organizational encouragement for innovation, quality of human resources available, and government support.

(Sharma et al., 2008) conducted an empirical investigation of RFID adoption model based on strategic choice and institutional theories. They used a multi-stage model approach and identified the factors that are critical in the evaluation, adoption, and integration stages of RFID adoption. They found out that perceived costs and current top management support are positively related to the intent to evaluate RFID technology. They also found that current top management support, presence of IS infrastructures for supporting tracking and scanning are positively related to RFID adoption intent for future while top management support in the past for adoption of other technologies is negatively related to RFID adoption. Perceived benefits and perceived costs, standards or privacy issues are insignificant and do not matter to determine future adoption intent. Finally, they found that IS infrastructure and coercive pressures are likely to drive the decision to integrate RFID technology in future and top management support and perceptions of standard stability drives the current adopters to go to the integration stage. Normative pressure positively influences the extent of integration with partners across supply chain and internally within the business processes while IS capabilities are negatively related to both external and internal integration.

In an empirical study of factors affecting RFID's adoption in Taiwan (Shih et al., 2008) found seven factors influencing the adoption decision. These factors are operational, manufacturing, and supply chain efficiencies, organization context, investment cost, market environment, and technology characteristics.

Brown and Russell (2007) conducted an exploratory study of factors influencing RFID adoption in South African retail organizations. The authors found that RFID adoption intention was predicted by technological factors that included relative advantage, compatibility, complexity, and cost; organizational factors that included top management attitude, information technology expertise, organization size, and organizational readiness; and finally, environmental factors that included competitive pressure, external support, and existence of change agents.

In their field study of RFID deployment, (Whitaker et al., 2007) found that RFID implementation spending and partner mandate are associated with an expectation of early return on RFID investment, and perceived lack of standards is associated with an expectation of delayed return on investment. They argue that firms with broad IT application deployment and a critical mass of RFID implementation spending are more likely to report early returns from RFID investments.

(Lee and Shim, 2007) conducted an empirical study of RFID adoption in healthcare industry and found out that three categories of factors, technology push, need pull, and presence of champions determine the likelihood of adopting RFID within organizations. They also found that the relationships between these categories and the likelihood of adopting RFID are moderated by organizational readiness.

In their study (Lu et al., 2006) emphasized that adoption costs, technological performance, standards, and need of interaction between partners are important for RFID diffusion.

From the summary of empirical studies on the determinants of RFID adoption, it can be seen that most of the factors are technological, organizational, or environmental in nature. Thus the use of TOE framework for this dissertation research is appropriate. Also, the results on the effects of organizational and environmental factors on RFID adoption vary with industrial or cultural context. Thus there is a need to analyze the factors of RFID adoption for better understanding of the adoption process in a particular industrial context.

2.2. Summary

This chapter has provided an overview of the theoretical foundation that is used in this research. Rogers' theory of diffusion of innovation, technology-organization-environment framework, and theory of business value of IT are discussed. These theories allow putting the findings into a theoretical perspective and provide a basis for enriched discussion of the findings at the same time. A theoretical frame of reference is developed by providing a detailed review of the literature on RFID research including technical overview, RFID in the context of supply chain management, and empirical and analytical studies on the pros and cons, and adoption of RFID.

Chapter 3

Research Design and Methodology

This chapter reports the epistemological position and the research design employed for this dissertation research.

The focused dissertation research work is based on soft-systems approach. (Checkland, 1999) describes two types of systems approaches: hard and soft systems thinking. Hard systems thinking focuses on the use of mathematical models and simulation while soft systems thinking focus on solving problems in systems involving or interacting with people. According to hard systems thinking (Churchman, 1968) an objective reality exists where the researcher can distinguish the whole system. The perspective used in this dissertation work is the soft-systems way of thinking where the reality is described in subjective terms and the researcher tries to distinguish the whole system. Within the systems approach distinction is made between open and closed systems. A closed system is supposed to be self-contained and does not interact with its environment whereas an open system interacts with its environment. As the focus of this dissertation is the retail value chain where the entities interact with each other, it is naturally considered as an open system. Also for the retail industry to be studied, the surrounding environment needs to be considered since it is always present and influences the retail operations.

Scientific reasoning is divided into being inductive or deductive. Deductive reasoning starts with existing theories and concepts, and formulates hypotheses which are subsequently put to test (Gummesson, 2000). Inductive reasoning on the other hand follows the opposite path and starts with empirical study, and categories, concepts, models or frameworks and eventually theories emerge from this input (Gummesson, 2000; Chalmers, 2002). The systems approach acknowledges both inductive and deductive reasoning. However according to Gummesson (2000) only the starting point of research separate deductive and inductive research. After the initial stage, all types of research become an iterative process between deductive and inductive and imply a learning loop between empirical study and theory which holds for this research work as well.

This dissertation work begins with an inductive approach. Initially the study was not governed by explicit theories or hypotheses. It started with an open-ended empirical investigation and theoretical elements were gradually embedded. Moreover, it was during the research process that the research focus emerged which is also a characteristic of inductive research approach. The primary reason for conducting this research based on inductive reasoning is due to the nature of the research area itself. The interdisciplinary nature and the newness of RFID technology implementation in commercial applications made it difficult to start with a particular existing theory and then formulate hypotheses. Starting with empirical studies and simultaneously searching for relevant theories and disciplines that might fit within the empirical studies, eventually allowed determining and understanding the research focus. This dissertation is primarily concerned with better understanding and improving the RFID adoption in retail and is thus applied in nature and hence justifies the use of inductive reasoning. The research questions set out earlier are practical management problems which suggest the use of empirical studies as natural starting point with an inductive reasoning lens. The epistemological lens reflects on the choice of research methods used in this dissertation work.

Due to the fact that the use of RFID in the retail sector for operational and value chain improvement is a rather new area it became clear during the research planning phase that the methodology must be suitable for the analysis of data as it could not be expected to find a representative sample of participants for an empirical survey. Therefore a combination of secondary and primary data sources provided the data for this research work and a mixed method design was used.

Mixed method (Tashakkori and Teddlie, 2003) design is a procedure for collecting, analyzing and mixing both quantitative and qualitative data at some stage of the research process within a single study, to better understand a research problem (Creswell, 2002). The rationale for mixing is that neither quantitative nor qualitative methods are sufficient by themselves to capture the details of a situation, such as a complex issue of the impact of RFID. When used in combination, quantitative and qualitative methods complement each other and allow for more comprehensive analysis (Green et al., 1989, Tashakkori and Teddlie, 1998).

In quantitative research, the researcher relies on numerical data (Charles and Mertler, 2002). The researcher develops hypotheses and questions and use measurement and observation of specific variables for the test of theories. Also, the researcher himself/herself determines which variables to investigate and chooses instruments that will yield reliable and valid results. On the other hand qualitative research is "an inquiry process of understanding" where the researcher develops a "complex, holistic picture, analyzes words, and conducts the study in a natural setting" (Creswell, 1998, p. 15). In qualitative research, data is collected from those immersed in everyday life of the setting in which the study is framed and the data analysis produces an understanding of the problem based on contextual factors (Miller, 2000). In a mixed methods approach, the researcher chooses approaches, as well as variables and units of analysis, which are most appropriate for finding the answer to their research questions (Tashakkori and Teddlie, 1998). As quantitative and qualitative methods are compatible both numerical and text data, collected sequentially or concurrently, can help better understand the research problem.

While designing a mixed methods study, three issues need consideration: priority, implementation, and integration (Creswell et al., 2003). Priority refers to which method, either quantitative or qualitative, is given more emphasis in the study. Implementation refers to whether the quantitative and qualitative data collection and analysis occurs in sequence, or in parallel or concurrently. Integration refers to the phase in the research process where the mixing or connecting of quantitative and qualitative data occurs.

This study uses sequential explanatory mixed methods design, consisting of two distinct phases (Creswell et al., 2003). In the first phase, the qualitative textual data is collected to identify key issues of research thrust. In the second phase, a quantitative Delphi technique is used to collect numerical data using a questionnaire to help develop and test theory. The priority in this design is given to the quantitative Delphi method, because the quantitative research represents the major aspect of data collection and analysis in this study, focusing on in-depth explanations of quantitative results. The qualitative component goes first in the sequence and is used to reveal the key research issues that need investigation. The quantitative and qualitative methods are integrated at the beginning of the quantitative phase while developing the Delphi study questions based on the results of the qualitative phase. The results of the two phases are also integrated during the discussion of the outcomes of the whole study.

Sequential mixed method research design is easy to implement for a single researcher, as it sequentially proceeds from one stage to another. Also such a sequential approach is useful for exploring research results in more detail (Creswell, 1998; Creswell, 2002).

Mixed method is appropriate for this research since RFID research is still at its infancy and thus a combination of methodological techniques better assists in exploring the impact of the technology and the adoption process more fully. This can only be obtained by performing a content analysis of the topic. Content analysis is the qualitative method used in this dissertation. The content analysis is performed manually so that no piece of relevant information is ignored. The findings from the content analysis act as an input for the following Delphi study. Delphi method is used to cross check the findings from the content analysis as well as to unveil other pertinent issues like adoption process, diffusion strategy etc. that are important for narrative discussion and conceptual framework development. The two methods are well established scientific methods that are widely used in IS (Information Science) research and are suitable to meet the research objectives. The Delphi study in light of the content analysis findings is used to develop RFID impact and adoption frameworks as per the objectives of this dissertation research. The two research methods that this dissertation employs are discussed in the following sections.

3.1. Content analysis

Content analysis is a research technique for making valid inferences from texts or other meaningful matter to the contexts of their use (Krippendorf, 1980). It is defined as the detailed and systematic examination of the contents of a particular body of materials for the purpose of identifying patterns, themes or biases (Leedy and Ormrod 2005, p. 143). There are four major functions of content analysis: confirmation of what is believed, correction of the existing illusions of specialists, settling disagreements among specialists, and finally formulating and testing hypotheses about symbols. The methodology is both qualitative and quantitative (Leedy and Ormrod 2005, p. 143). The reason is that it allows establishing relationships between themes making it qualitative. Content analysis also allows counting the frequency of occurrence of particular words in the text and provides means for statistical analysis, thus making it quantitative as well. Content analysis is a form of semiotics or hermeneutics like conversation analysis and discourse analysis (Krippendorff, 1980). Like hermeneutics, semiotics is an underlying philosophy and a mode of analysis. (Liebenau and Backhouse, 1990) demonstrated the applicability of semiotics in information systems (IS) research. Lee's (1994) work on electronic mail as a medium for rich communication using hermeneutic interpretation showed the potential of this exploratory mode of analysis. Wynn's (1991) is an example of the use of conversation analysis in IS research whereas (Klein and Truex, 1995) work shows the use of discourse analysis in IS.

In this dissertation research, the content analysis material is restricted to textual documents which are a variety of online articles including journal publications, conference proceedings, academic magazine articles, industry white papers, and news releases. The materials that are subjected to the analysis are carefully selected after thorough reading to make sure about relevance to the research topic. The choice of articles is restricted to those written from the year 2000 onwards considering that RFID technology has been commercialized and has become relevant to businesses and consumers in the last 8 years and thus the most relevant literature about the topic has been published during this period.

In order to ensure higher accuracy of the gathered data, multiple data sources are used. This approach is called triangulation which allows for a greater certainty of the accuracy of the data because it reduces the risks of individual biases and enables validation through crosschecking (Knight, 2002). Also to ensure reliability of the coding of the data computer aided content analysis is employed for 10% of the total number of articles chosen randomly from the entire corpus of the dataset. The coding process will be discussed in detail in later sections.

3.2. Delphi technique

Delphi 'technique' is the second method used for this dissertation work. It is a method to combine the informed judgments from a panel of independent experts. This method is relevant when no or very little hard data or well-established theory is available, but experts have relevant information about the focus of the research. It is a procedure that is based on the premise that aggregation reduces the error of individual responses.

The ‘Delphi technique’ is a very old method that dates back to the 1959s, developed by a team of researchers named Dalkey and Helmer. According to Dalkey (1969) the Delphi method has three primary features which are anonymity, controlled feedback and iteration, and formal group judgment. Each respondent submits his own independent answer to the relevant questions in the interview/questionnaire. The rationale behind the anonymity feature is that anonymity restricts possible bias that could arise from peer pressure or dominant individuals. The results of a given round of responses are summarized and reported to the group who are then asked to reassess their replies in light of the feedback. The premise is that iteration with feedback allows interchange among the members of the group in a controlled manner. Finally, the group answer is presented as a formal aggregation given the final set of individual answers. The group judgment may be formulated as the mean or median of the responses. The formal aggregation allows for a well-defined and well-represented group response thus eliminating individual error of responses.

3.3. Data collection

3.3.1. Content analysis data collection

3.3.1.1. Content analysis sampling design

First, possible sources were identified as targets for the search. The search covered popular on-line sources, such as *RFID Journal*, *RFID Gazette*, *TechRepublic*, and major academic on-line databases, such as *ABI INFORM*, *ACM Digital library*, and *IEEE Explore*. Different versions of the keyword containing "*RFID*" and "*Retail*" were used and relevant articles were collected. The search was conducted between the period of October 2006 – April 2009 and 630 articles were collected. Out of the 630 articles, there were 58 published journal articles, 54 conference proceedings, 90 academic magazines, 234 industry white papers, and 194 news releases. All duplications were eliminated. For the news releases, the majorities consisted of insights from pilot studies or actual RFID implementations or views from experts in light of empirical investigations. Please note that the data for content analysis has been collected over 4 different time periods between October 2006 - April 2009 to build a superset of data. It was made sure that the final dataset has well distributed data both from academic and non-academic sources.

3.3.1.2. Variables of interest

Variables representing potential benefits, RFID applicable business processes, relevant value chain activities, adoption challenges, and technology choice were the focus for the content analysis phase of this dissertation research.

3.3.1.3. Coding procedures

Both theoretical/selective coding and open coding techniques have been used for coding the data that is collected. Theoretical or selective coding is defined as the process of delimiting the theory to a few core variables which act as a guide for data collection and analysis (Fernandez, 2004; Glaser, 1978).

Open coding is a part of grounded theory approach for data analysis developed by Glaser and Strauss. The main features of open coding include: a) the inductive development of initial categories b) ongoing testing of categories through conceptual analysis and comparison of categories with data that is already coded, and c) altering or eliminating the existing categories as new categories emerge (Strauss, 1987; Trauth, 2000).

Open coding technique was used as an iterative process to uncover important factors that are relevant to understanding the impact of RFID technology on the value chain. Open coding technique was used to identify the potential benefits, RFID-applicable business processes, adoption challenges, and technology choice and selective coding technique was used to identify the RFID-applicable value chain activities in this research.

3.3.1.4. Coding categories

The coding categories that have been developed after an iterative process of refinement are discussed in detail below:

1. Potential benefits (Used open-coding technique)
    a. Improved customer service levels: Does the article suggest that improved customer service level is a potential benefit of RFID?
    b. Security against theft/fraud/loss/counterfeiting: Does the article suggest security against theft / fraud/ loss / counterfeiting is a potential benefit of RFID?
    c. Reduced out of stock: Does the article suggest that reduced out of stock is a potential benefit of RFID?
    d. Improved data accuracy: Does the article suggest that data accuracy is a potential benefit of RFID?
    e. Accuracy, speed, or efficiency of process: Does the article suggest that increased accuracy, speed, or efficiency of process is a potential benefit of RFID?
    f. Real-time visibility: Does the article suggest that real-time visibility is a potential benefit of RFID?
    g. Reduced inventory: Does the article suggest that reduced inventory is a potential benefit of RFID?
    h. Increased sales: Does the article suggest that increased sales is a potential benefit of RFID?

i. Business intelligence: Does the article suggest that business intelligence is a potential benefit of RFID?

j. Improved collaboration: Does the article suggest that improved collaboration is a potential benefit of RFID?

k. Improved returns / recall handling: Does the article suggest that improved returns / recall handling is a potential benefit of RFID?

l. Reduced overall cost: Does the article suggest that reduced overall cost is a potential benefit of RFID?

m. Improved visibility of orders and inventory: Does the article suggest that improved visibility of orders and inventory is a potential benefit of RFID?

n. Reduced labor requirements / costs: Does the article suggest that reduced labor requirements / cost is a potential benefit of RFID?

o. Improved on-shelf availability: Does the article suggest that improved on-shelf availability is a potential benefit of RFID?

p. Reduced shrinkage: Does the article suggest that reduced shrinkage is a potential benefit of RFID?

q. Improved asset management: Does the article suggest that improved asset management is a potential benefit of RFID?

r. Improved labor productivity: Does the article suggest that labor productivity is a potential benefit of RFID?

s. Tracking shopping behavior: Does the article suggest that tracking shopping behavior is a potential benefit of RFID?

t. Tracking temperature: Does the article suggest that tracking temperature is a potential benefit of RFID?

u. Competitive advantage: Does the article suggest that competitive advantage is a potential benefit of RFID?

v. Monitoring worker productivity: Does the article suggest that monitoring worker productivity is a potential benefit of RFID?

2. RFID applicable business processes (Used open-coding technique)

   a. Tracking and tracing: Does the article suggest that tracking and tracing is an RFID applicable business process?

   b. Replenishing: Does the article suggest that replenishing is an RFID applicable business process?

   c. Receiving: Does the article suggest that receiving is an RFID applicable business process?

   d. Checkout: Does the article suggest that checkout is an RFID applicable business process?

   e. Demand forecasting / planning: Does the article suggest that demand forecasting / planning is an RFID applicable business process?

   f. Reuse and recycle / Returns: Does the article suggest that Reuse and recycle / Returns is an RFID applicable business process?

   g. Shipping: Does the article suggest that shipping is an RFID applicable business process?

h. Picking: Does the article suggest that picking is an RFID applicable business process?

i. Ordering: Does the article suggest that ordering is an RFID applicable business process?

j. Transport: Does the article suggest that transport is an RFID applicable business process?

k. Storing: Does the article suggest that storing is an RFID applicable business process?

3. RFID applicable value chain activities (Used selective/theoretical coding technique)

   a. Replenishment and scheduling: Does the article suggest that replenishment and scheduling is an RFID applicable value chain activity?

   b. Warehouse management and distribution: Does the article suggest that warehouse management and distribution is an RFID applicable value chain activity?

   c. In-store operations: Does the article suggest that in-store operation is an RFID applicable value chain activity?

   d. Sales planning: Does the article suggest that a sales planning is an RFID applicable value chain activity?

   e. Sales: Does the article suggest that sales is an RFID applicable value chain activity?

f. Returns/Recalls: Does the article suggest that returns / recalls is an RFID enabled value chain activity?

g. Promotion planning: Does the article suggest that promotion planning is an RFID applicable value chain activity?

h. Merchandise planning: Does the article suggest that merchandise planning is an RFID applicable value chain activity?

i. Price management: Does the article suggest that price management is an RFID applicable value chain activity?

j. Assortment planning: Does the article suggest that assortment planning is an RFID applicable value chain activity?

4. RFID implementation challenges (Used open-coding techniques)

   a. Privacy issues: Does the articles suggest that privacy issue is a challenge / inhibitor for RFID implementation?

   b. High cost: Does the articles suggest that high cost is a challenge / inhibitor for RFID implementation?

   c. Readability: Does the articles suggest that readability is a challenge/inhibitor for RFID implementation?

   d. Data warehousing and integration issues: Does the articles data warehousing and integration issue is a challenge / inhibitor for RFID implementation?

   e. Lack of standards: Does the articles suggest that lack of standards is a challenge/inhibitor for RFID implementation?

f. Business process redesign: Does the articles suggest that business process redesign requirement is a challenge / inhibitor for RFID implementation?

g. Unclear ROI: Does the articles suggest that unclear ROI is a challenge / inhibitor for RFID implementation?

h. Multiple frequencies: Does the articles suggest that multiple frequency choice is a challenge / inhibitor for RFID implementation?

i. Resistance to change: Does the articles suggest that resistance to change is a challenge / inhibitor for RFID implementation?

j. Lack of top management support: Does the articles suggest that lack of top management support is a challenge / inhibitor for RFID implementation?

k. Lack of technical expertise: Does the articles suggest that lack of technical expertise is a challenge / inhibitor for RFID implementation?

l. Complexity of technology: Does the articles suggest that complexity of technology is a challenge / inhibitor for RFID implementation?

5. RFID technology choice (Used open-coding techniques)

   a. UHF reader: Does the articles suggest that UHF reader is a technology choice for retail?

b. HF reader: Does the articles suggest that HF reader is a technology choice for retail?

c. Near field UHF reader: Does the articles suggest that near field UHF Reader is a technology choice for retail?

d. LF reader: Does the articles suggest that LF reader is a technology choice for retail?

e. Pallet level tagging: Does the articles suggest that pallet level tagging is a technology choice for retail?

f. Case level tagging: Does the articles suggest that case level tagging is a technology choice for retail?

g. Item level tagging: Does the articles suggest that item level tagging is a technology choice for retail?

h. Passive tags: Does the articles suggest that passive tags is a technology choice for retail?

i. Active tags: Does the articles suggest that active tags is a technology choice for retail?

j. Passive dual frequency tags: Does the articles suggest that Passive dual frequency tags is a technology choice for retail?

Table 3-1 and Table 3-2 below show the coding categories that are developed during the content analysis phase of this research.

Table 3-1. Benefits and business processes coding categories

Benefits	Business Processes
Improved customer service levels	Tracking/Tracing
Security	Replenishing
Reduced out of stock	Receiving
Improved data accuracy	Checkout
Accuracy, speed, or efficiency of process	Demand Planning
Real-time visibility	Re-use and recycle/Returns
Reduced inventory	Shipping
Increased sales	Picking
Business intelligence	Ordering
Improved collaboration	Transport
Improved returns/recall handling	Storing
Reduced overall cost	
Improved visibility of orders and inventory	
Reduced labor requirements/costs	
Improved on-shelf availability	
Reduced shrinkage	
Improved asset management	
Improved labor productivity	
Tracking shopping behavior	
Tracking temperature	
Competitive advantage	
Monitoring worker productivity	

Table 3-2. Value chain activities, challenges, and technology choice coding categories

Value Chain Activities	Challenges	Technology Choice
Replenishment	Privacy issues	UHF reader
Warehouse management and distribution	High cost	HF reader
In-store operations	Technical issues (Readability)	Near field UHF reader
Sales planning	Data warehousing and integration	LF reader
Sales	Lack of standards	Pallet level tagging
Returns / Recalls	Business process Redesign/Complexity	Case level tagging
Promotion planning	Unclear ROI	Item level tagging
Merchandise planning	Multiple frequencies	Passive tags
Price management	Resistance to change	Active tags
Assortment planning	Top management attitude	Passive dual frequency tags
	Lack of technical expertise	
	Complexity of technology	

3.3.1.5. Coding reliability

To ensure coding reliability the dataset was visited three times in order to make sure that some important aspect within a particular article is not missed. The coding categories emerged as a result of a continuous repetitive process. To validate the manual coding scheme computer aided content analysis was performed using open source software program called textStat on a randomly selected 10% of the total number articles (which is 47 articles) from the data corpus. TextStat gives the frequency counts of each word within an article. This word frequency list was compared with the primary coding schema and was treated as the coding schema from a secondary coder. After comparing the two coding schemas, the level of coding agreement was calculated.

To ensure inter-coder reliability, Holsti's (1969) formula for reliability was used.

Reliability= 2(OA) / (N1 + N2)

OA= Observed Agreement

N1= No. of coding decisions made by the primary coder

N2= No. of coding decisions made by the secondary coder

Based on the above formula the level of agreement between primary manual coding scheme and secondary computer aided coding is 99.21%.

3.3.1.6. Coding analysis

The data collected through the coding procedure is submitted to the statistical software program SPSS. Frequencies of articles are run on the variables to analyze their incidence in the academic and trade articles within the data corpus. Variables are ranked based on corresponding frequencies or percentage of articles.

3.3.2. Delphi study data collection

3.3.2.1. Candidate selection criteria

In order to reduce bias from a group composed of candidates of similar backgrounds, candidates from different sectors such as consulting, academia (faculty researchers), retail, and third party service providers were obtained. This allowed achieving a broad overview and eliminating inherent bias in each sector. This also allowed comparing conclusions from inherently different views amongst these sectors. The fundamental characteristics and qualifications required for candidates were: history of association with RFID projects either at management, operational, or research level, individuals who are viewed as experts and are self motivated and forward thinking (NRC, 1998).

3.3.2.2. Number and distribution of candidates

A total of 74 expert candidates, including consultants (23; 31.1%) academics (17; 23%) retail practitioners (16; 21.6%), and third-party service providers (18; 24.3%)

participated in this study. Figure 3-1 below shows the distribution of the experts across different business associations.

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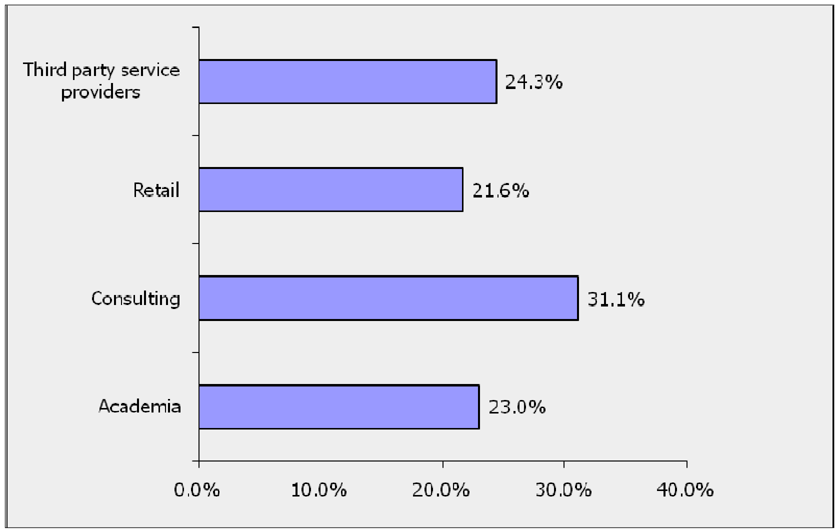


Figure 3-1. Experts by business association

The opinions of experts across the spectrum of management levels were also obtained. Among the 74 expert candidates, (28; 37.8%) held top management positions, 8 (10.8%) held IT management positions, (19; 25.7%) were executives, and (19; 25.7%) held research positions. Figure 3-2 shows the distribution of experts across level of positions that they hold.

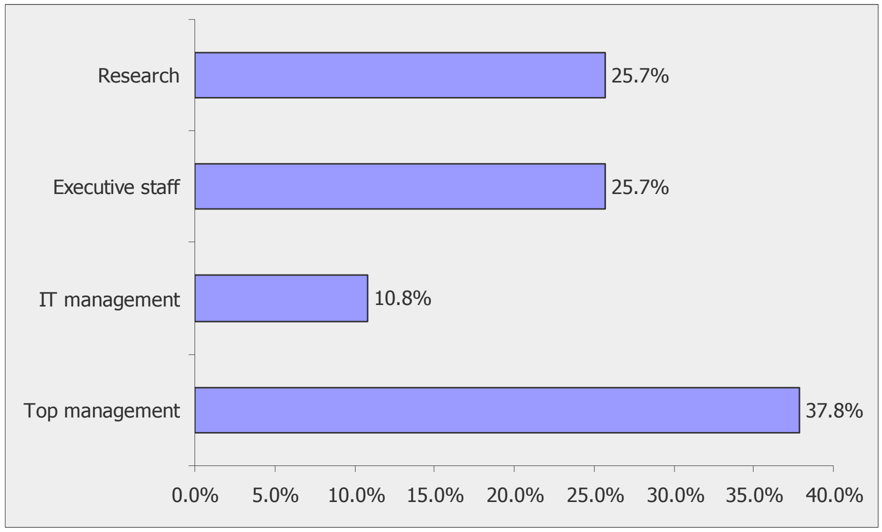


Figure 3-2. Experts by job position

About (44; 59.5 %) of the experts claimed that they have very good knowledge about RFID and (26; 35.1%) claimed that they know all about RFID. Figure 3-3 shows the distribution of the experts in terms of their RFID knowledge level.

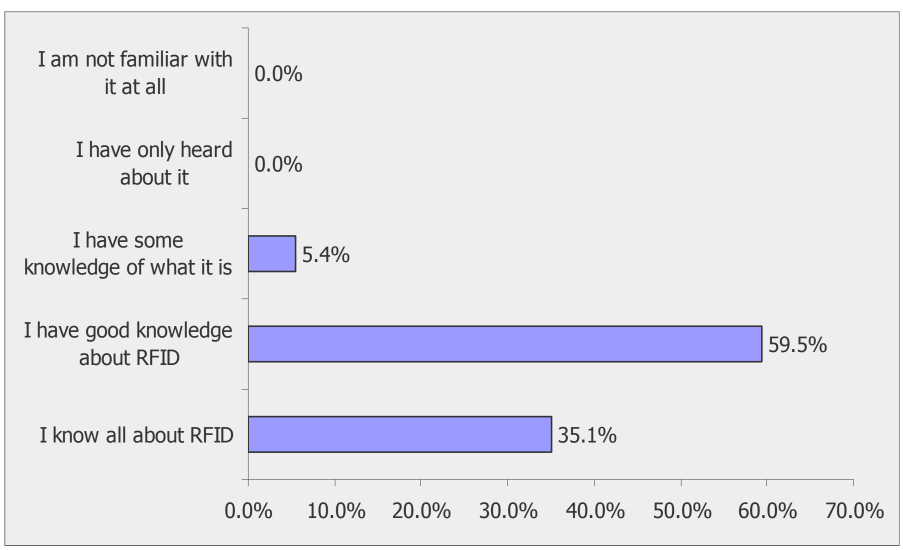


Figure 3-3. Experts by RFID knowledge level

Finally (29; 39.7%) out of the 74 candidates have greater than five years of involvement with RFID projects, (22; 30.1%) have 3-5 years of involvement, 14; 19.2%) have 1-3 years of involvement, and (8; 11%) about six months of involvement with RFID projects. Figure 3-4 shows the distribution of the experts in terms of their RFID experience level.

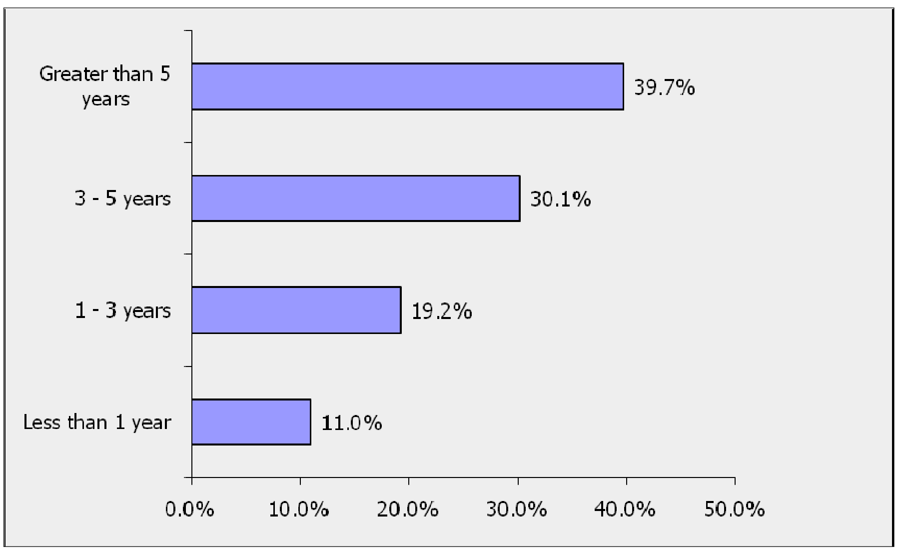


Figure 3-4. Experts by RFID experience level

A total of 74 expert candidates well distributed across different sectors and positions allowed enough depth in responses and at the same time ensured manageability of the respondents.

3.3.2.3. Questionnaire design

The questionnaire guiding the Delphi study was generated primarily based on the results of the content analysis as well as under the guidance of the fundamental theories that served as the premise of this work. In this research, the goal was to better understand the impact of RFID and to explore the underlying rationale in adoption of RFID technology in the retail sector. The instrument was developed to measure the research variables. To increase the validity and reliability of the instrument and to pretest the data collection procedure, it was tested with faculty and doctoral students. They were asked to provide comments regarding the content and readability of the questionnaire. After the pretest, further refinement was made according to the comments received to prepare the final questionnaire for the Delphi study. This procedure was performed to achieve content validity and to reduce any confusion within the questions.

Appendix A shows all of the items included in the questionnaire. The questionnaire contained nine sections. The first section of the questionnaire was designed to assess participant information such as their business association, job position, level of RFID knowledge, and level of RFID experience. Section two included questions capturing the impact of RFID on retail sector in terms of RFID benefits, RFID applicable business processes and relevant value chain activities, and challenges for RFID adoption. Instructions were given to the experts so that they think about certain consumer products like grocery, dvds and games, furniture, tableware, accessories, health and beauty products, alcohol and cigarettes, electronics etc. while answering the questions. Section three included questions about technology choice in terms of frequency levels, tag types, tagging levels, current adoption status in retail, business value dimension, and diffusion strategy. Section four included questions related to technological factors influencing RFID adoption decisions (Relative advantage, cost, complexity, and compatibility). Section five included questions related to organizational factors influencing RFID adoption decisions (Top management support, size, and IT expertise). Section six included questions related to environmental factors influencing RFID adoption decisions (Competitive pressure, external support, and catalyst agents). Section seven included questions related to value chain factors influencing RFID adoption decisions (Information intensity and complexity). Section eight included a question about the perceived retail RFID adoption intent. Finally, section nine included questions related to the diffusion model (Knowledge, persuasion, design and decision, and implementation stages). For each question the participants were allowed to provide any additional comments if they choose to. The questionnaire was designed to develop the conceptual framework of the impact of RFID and the conceptual framework of RFID adoption process.

Measures from previous studies were adapted and amalgamated for ensuring reliability and validity of the study instrument (Premkumar and Roberts, 1999; Grover, 1993; Ranganathan and Jha, 2005; Sharma and Citurs, 2005; Brown and Russell, 2007). The instrument was developed iteratively using questions from prior literature and insights gained from content analysis. Detailed adaptation of the items will be discussed in the research model development sections within the discussion of results and findings.

3.3.2.4. Measurements

Each variable was measured by multi-item indicators. All the items except the items corresponding to respondent business association, job position, RFID knowledge level, and RFID experience level used a 5 point Likert-type scale ranging from strongly disagree (1) to strongly agree (5). The items corresponding to each of the research variables will be discussed in detail in the results and findings section.

The benefit variable assessed the potential of the technology and was measured by 22 items (identified from comprehensive content analysis). RFID applicable retail business process assessed the business processes that are improved by RFID technology and was measured by 11 items. RFID applicable retail value chain activity was measured by 10 items. Adoption challenge assessed the adoption inhibitors and was measured by 12 items. Technology choice in terms of frequency was measured by four items; tag type was measured by three items; and tagging level was measured by three items. Current retail RFID adoption status was measured by three items. Dimension of RFID business value was measured by three items. RFID diffusion strategy was measured by two items. Relative advantage was measured by six items. These items assessed the perceived benefits of RFID technology to retailers. Cost was measured by three items that assessed the degree to which cost constraint interferes with adopting RFID technology by retailers. Complexity assessed the difficulty to implement the technology and was measured by four items. Compatibility was measured by two items that determined whether RFID technology is compatible with the firm's beliefs, values, and work practices.

Top management support assessed the level of commitment of the decision makers using four items. Organizational size was measured by a single item. IT expertise assessed existing IT capabilities of retailers and was measured by three items.

Competitive pressure was measured by two items. External support evaluated the level of support from vendors and other agencies and was measured by four items. Catalyst agent assessed the presence of agents external to the organization promoting the adoption of the technology and was measured by four items.

Value chain information intensity assessed the information intensity in the retail value chain and was measured by four items. Value chain complexity assessed the complexity inherent in the retail value chain and was measured by two items.

Knowledge phase of RFID diffusion model was measured by two items; persuasion phase was measured by two items; design and decision phase was measured by three items; and implementation phase was measured by two items.

A single item was used to measure retailers RFID adoption intent as perceived by the experts which is the dependent variable in this dissertation research. As the intention to adopt a new technology is positively associated with the actual behavior in adopting the technology (Ajzen, 1985; Davis, 1989), this dissertation research assumes that retailers will be more likely to adopt RFID technology if they are believed to have stronger intent.

3.3.2.5. Procedure

This study used an electronic mailing method to communicate and collect the data through an online survey. The Delphi study was conducted between the period of December 2009 and January 2010. Participation in the study was voluntary and participants were assured that their responses would be confidential. Individualized email invitations were sent to around 240 expert candidates identified through personal contacts. The invitation email provided the necessary information about the research study and it contained a web link to direct the participants to the online questionnaire. After one week the first reminder email was sent and after the end of the second week the second and final reminder was sent. The reminder emails also contained the link to the questionnaire. This procedure was expected to maximize the response rate. After about three weeks since the initial invitation email was sent, around 80 responses were received, out of which 74 were deemed usable.

The response rate is 30.84% which is a significantly high number and could be explained by the use of personal contacts and personalized methods to contact the candidates. After the data from the first round of the Delphi study was collected, a summary report of the responses was compiled. Then another email was sent to each participants inviting them to participate in the second round of the Delphi study. The second email contained the summary report for reference of the experts in making their replies in the following round along with their individual responses and the web link to the questionnaire. The participants were allowed to change their opinions in light of the amalgamated results from the previous round if they choose to. The deadline for the second round of the Delphi study was set to two weeks. The participants were only required to respond to the questions for which they wanted to change their opinion in the second round. After the end of the two weeks three responses were collected from the participants who chose to change their opinions. The rest of the candidates kept their previous responses as their final opinion based on their prior experience and judgment. Delphi based rounds continue until a predetermined level of consensus is reached or no new information is gained. In this study, not much new information is gained after the second round and thus no follow up rounds were conducted. According to (Altschuld, 1993) two iterations are usually enough to obtain good estimate of the distribution and consensus view of participants and often not enough new information is gained to warrant the cost of more rounds. The responses from the two rounds were merged together at the end of the study to create the final data set for analysis for this study.

3.3.2.6. Analysis

The data collected from Delphi method was analyzed using the SPSS (Statistical Package for Social Science) software version 17.0. SPSS is widely used for conducting statistical analyses, manipulating data, and generating tables and graphs to summarize data. Descriptive statistics such as means and frequencies, factor analysis using principal component analysis, and multivariate discriminant analysis methods were used in this study.

Principal components method with varimax rotation was used to extract factors from benefits, RFID applicable business processes and value chain activities, and challenges.

Multivariate discriminant analysis was used to test the research hypotheses for developing both the RFID impact conceptual framework and the RFID adoption conceptual framework. The method provides a statistical procedure to identify the research variables that best discriminate between different levels of adoption intent. In distinguishing between the pre-defined groups relative importance of groups of variables was assessed along with the estimation of the relative importance of individual variables within a group. This is a more powerful and robust statistical procedure that provides a multivariate estimation compared to a bivariate t-test approach of comparing means of variables across different groups independently. The method derives a linear combination of one or more research variables that best discriminate between the pre-defined groups (Hair et al., 1983).

3.3.2.7. Validity and reliability

Validity and reliability of measurement model are important to consider in any research. Validity determines whether the method used for the study really measures what it is intended to do. There is no clearly defined way to know if a method is valid or not, however a careful analysis of the questions and the wordings that could influence the responses is one way to avoid making major mistakes. Reliability measures the consistency of the chosen method. A reliable study should produce the same result every time it is conducted using the same method.

The constructs of the questionnaire in this study were tested both for validity and reliability to ensure that the measurement was accurate and robust. Validity assesses the degrees to which items measure the theoretical construct whereas reliability assesses the stability of the scale based on an assessment of the internal consistency of the items measuring the construct (Churchill, 1979).

Validity of the instrument was assessed through content, convergent, and discriminant validity. Content validity assesses if the measurement covers the complete domain of the construct. Convergent validity assesses if all the items measuring the construct cluster together. Discriminant validity evaluates the degree to which a concept differs from other concepts. It is indicated by a measure not correlating very highly with other measures from which it should theoretically differ (Churchill, 1979). Please note that for some parts of the questionnaire the items are developed from scratch and are not borrowed from previous studies. Since those questions are intended to be exploratory in nature, they are only put to reliability test and content validity tests.

Content validity of the instrument in this research was established through a thorough iterative process of item selection and refinement. Most of the items measuring the constructs were derived from operationalizations used in previous studies. The items were adapted with minimal changes to suit this research context. Also extensive pre-testing of the items by a team of doctoral students and faculty ensured that the items were relevant and it measured the complete domain of the construct.

Convergent and discriminant validity was evaluated using principal component factor analysis. Factor analysis of multi-item indicators was used to evaluate if the theorized items for a construct converge together for convergent validity. Discriminant validity of the construct items was analyzed by looking at the extent of cross-loadings of an item on other factors where it did not theoretically belong.

Items that represent each individual construct were subjected to reliability analysis. Reliability of the constructs was evaluated using Cronbach's alpha and assessment of the inter-item correlation. Items corresponding to the questions that were exploratory in nature were put through reliability and content validity since there was no theory testing aspect to them.

Details of the validity and reliability measures of the instrument is discussed in the relevant results and discussion sections.

3.3.2.8. Ethical consideration

Ethical issues were addressed at each phase in this study. In compliance with the regulations of the Institutional Review Board (IRB), the permission for conducting the research was obtained. The Request for Review Form was filed providing information about the principal investigator, the project title and type, type of review requested, and number and type of subjects.

Request for research permission contained the description of the project and its significance, methods and procedures, participants, and research status. This research was accorded an exempt status (Exempt from institutional review board – IRB Review) by the office of research protection at the Pennsylvania State University, since the participants were not audio or video taped, the study was conducted in a normal social setting, the research topic did not fall in a sensitive category, and the subject population was over eighteen.

In order to ensure that the participants were informed about the purpose of the study and that their participation was voluntary an informed consent form was developed. The consent form stated that the participants were guaranteed certain rights, agreed to be involved in the study, and acknowledged that their rights are protected. A statement of the informed consent was affixed to the web survey that reflected compliance by participation.

The collected data is stored securely with password protection and encryption during the entire project. Only the researchers can identify the participants and the gathered data is presented anonymously. The participant identification data will be destroyed when this dissertation work is finished and examined and the results are published in academic conferences and journals.

My involvement (as a researcher) with data collection in the two phases of this study was different. In the first qualitative phase of the study, I assumed more of a participatory role and personal involvement with the research topic and data. Since I performed a manual content analysis of the research topic by collecting relevant articles and classifying the data based on the themes that emerged, I was a research instrument myself. This introduces a possibility for subjective interpretation of the concepts and themes being studied during generating coding scheme of the data and creates a potential for bias (Locke et al., 2000). Extensive verification procedures, including iterative development of the coding scheme, triangulation of data sources, and performing a computer-aided content analysis on 10% of the total number of articles to establish inter-coder reliability was used to establish the accuracy of the findings and to control some of the potential researcher bias issues. Furthermore, a careful audit was done by the researcher's academic advisor and dissertation supervisory committee on all research procedures and data analysis in the study. In the second quantitative phase of the study, I administered the online Delphi study and collected the data using the standardized procedures after performing the reliability and validity checks of the instrument. The data analysis was performed using rigorous statistical analysis techniques.

3.4. Research procedure

First, formal iterative content analysis of the academic and trade articles was performed in this dissertation research. The content analysis research phase consisted of three major stages discussed below:

1. Reference identification and search: In this stage, the possible sources as targets for search were first identified. Then different versions of the keyword containing "*RFID*" and "*Retail*" were used to collect 630 relevant articles.
2. Classification: After collecting the data, the textual data was classified and each research issue was associated with a stage in the RFID diffusion model adapted from Rogers (1995). The various issues that emerged in the

classification phase were the following: potential benefits, RFID-applicable business processes, value chain activities that could be influenced by RFID, RFID technology choices in terms of frequency standards, tagging levels, tag types, and adoption challenges. The knowledge stage of the adapted RFID impact model involves enhancing the required information about the various aspects of the technology such as technological characteristics and the status of adoption of the technology. The persuasion stage involves favorable or unfavorable attitude being developed about the technology and it maps to potential benefits of the technology. The decision and design stage incorporates activities that led to deciding whether to adopt or reject a particular RFID solution. Information related to RFID applicable business processes, value chain activities, and the choice of technology in terms of tagging level (case, pallet, or item) or frequency standard contributes to the design and decision stage of the model. Finally, the implementation stage involves the technology actually starting to be used and it maps to implementation challenges and diffusion strategy. Figure 3-5 below shows the basic RFID impact model that is developed inspired by Rogers' stage model in the theory of innovation diffusion. The various stages of the model are inter-related and are connected via feedback loop. The argument is that these issues are also inter-linked and cannot be studied standalone. They need to be studied using an integrated lens which is the fundamental argument in this dissertation.

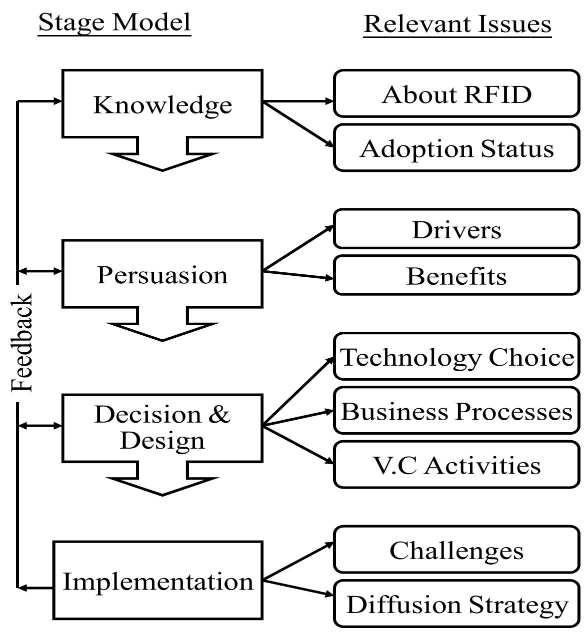


Figure 3-5. Basic research model

3. Data analysis and interpretation: Finally in the data analysis phase article frequency data was used to rank the factors in order of significance.

The results from the content analysis in light of the guiding theories were used as the means to develop the questionnaire for the Delphi study. Two iterations were used in the Delphi study for this dissertation research. Figure 3-6 below shows the research diagram demonstrating the research process that is employed in this dissertation study. The overall results from the Delphi study were used to develop the two conceptual frameworks of RFID impact and adoption.

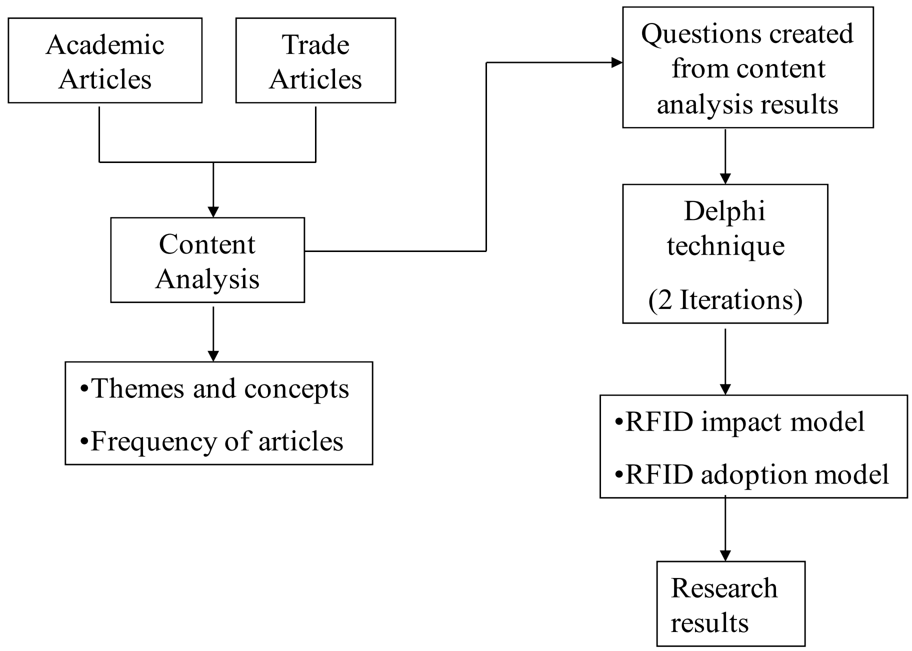


Figure 3-6. Research process

3.5. Summary

This chapter discusses the sequential mixed method research design employed in this dissertation research. Data collection process for the two research methods of content analysis and Delphi study is discussed. First, content analysis data collection process is described focusing on sampling design, variables of interest, coding process and categories, coding reliability, and coding analysis. Then the data collection process employed for the Delphi study is discussed with emphasis on candidate selection criteria, questionnaire design, measurements, analysis, and validity and reliability of the instrument. Finally, the overall research process used in this study is discussed.

Chapter 4

Data Analysis and Discussion: A Conceptual Framework of Impact of RFID

This chapter reports the preliminary data analysis results from content analysis and Delphi study including reliabilities of the measurements, descriptive statistics, and statistical tests including factor analysis, analysis of variance (ANOVA), multivariate analysis of variance (MANOVA), and multivariate discriminant analysis (MDA) to test hypotheses. The goal is to develop the conceptual framework of the impact of RFID which could be generalized for other automatic identification technologies as well. First, the content analysis results are reported. These results are integrated with the Delphi study while developing the questionnaire. The conceptual framework of impact of RFID is developed primarily from the Delphi data.

4.1. Descriptive results from content analysis

The content analysis analytical results and discussion are framed according to the stage in which they occur in the research model presented in Figure 3-5. Some issues identified in the stage model falls within the scope of content analysis phase of this research. Other significant issues that are identified during the content analysis but could not be quantified due to lack of adequate information are addressed during the Delphi study phase of this research. From the content analysis, issues that are addressed and discussed include: potential benefits of RFID, RFID applicable value chain activities and business processes, and adoption challenges.

General information about the technology within the knowledge stage has a much wider scope and any technical or contextual information about the technology maps to that stage and is thus beyond the scope of this research. The focus is to acknowledge that general awareness about the technology, its technological and organizational characteristics, current RFID adoption status etc. are extremely important and such awareness is a prerequisite for widespread RFID adoption to become a reality. However those issues are not captured by content analysis due to lack of adequate information. Information about RFID adoption drivers corresponding to the persuasion stage is also not captured by content analysis due to lack of information. However the textual articles indicated the importance of the concept of adoption drivers influencing RFID adoption. Thus RFID adoption process is investigated in detail during the Delphi study phase of this research. Table 4-1 shows the research issues that have been investigated using content analysis. Other issues shown in Figure 3-5 that are identified during the content analysis phase but could not be quantified are investigated using the Delphi method and will be discussed next.

The main purpose of this study was to examine the impact of RFID on retail value chain. The content analysis was performed to identify key research issues and was based on 630 articles published during the period of 2002 and 2009. Several variables including potential benefits, RFID applicable business processes and value chain activities, and implementation challenges are coded and the findings corresponding to those variables are discussed next. The analytical results and discussion are framed according to the stage in which they occur in the RFID adoption model. The discussion starts with the persuasion stage and key RFID retail benefits are identified. To address the decision and design phase, the most significant RFID-applicable retailer business processes and value chain activities, and choice of technology in terms of frequency, tag type, and tagging levels are identified. And finally to address the implementation phase the major challenges are identified.

Table 4-1. Research issues investigated using content analysis

Stages	Research Issues
Persuasion	Benefits
Design and decision	Business processes Value chain activities Technology choice
Implementation	Challenges

4.1.1. Content analysis of benefits of adopting RFID

Starting with the entire set of RFID related articles, 1685 instances were observed that mention one or more specific RFID benefits for retail sector. Table 4-2 shows the frequency and percentage of articles supporting each benefit. The most important benefits that are identified include improved customer service levels, security against theft or fraud, reduced out of stock, improved data accuracy, accuracy, speed and efficiency of processes, and real-time visibility.

Table 4-2. Benefits from RFID implementation

Benefits	Frequency	Percentage
Improved customer service levels	160	9.5%
Security against theft/fraud/loss/counterfeiting	154	9.14%
Reduced out of stock	135	8.01%
Improved data accuracy	121	7.18%
Accuracy, speed and efficiency of process	115	6.82%
Real-time visibility	100	5.93%
Reduced inventory	82	4.87%
Increased sales	82	4.87%
Business Intelligence	81	4.81%
Improved collaboration	81	4.81%
Improved returns/recall management	81	4.81%
Reduced overall cost	77	4.57%
Improved visibility of orders and inventory	74	4.39%
Reduced labor requirements/costs	70	4.15%
Reduced missing sales	68	4.04%
Reduced shrinkage	54	3.2%
Improved asset management	52	3.09%
Improved labor productivity	35	2.08%
Tracking shopping behavior	22	1.31%
Tracking temperature	21	1.25%
Competitive advantage	17	1.01%
Monitor worker productivity	3	0.18%
Total	1685	100%

The identified benefits are briefly discussed below:

1. Improved customer service levels: RFID can make shopping more convenient for the customers. RFID tagging of products improves access to data thus making it easier to find them. RFID tags can be helpful to retail stores and provide better customer services through better product / service identification. Prada's flagship store in New York puts RFID tags

on all its garments. When a customer selects a product, the employee working in the store can monitor the customer and provide a complete image and other characteristics of the product (Bednarz, 2002) thus enhancing the customers shopping experience.

2. Security against theft and fraud: Before RFID technology, theft prevention was done through observation. Employees were responsible for monitoring customers by observing their behavior to prevent theft. With the introduction of RFID tags, employees can track products / services to prevent theft in stores.
3. Reduced out-of-stock: By increasing accuracy in inventory data RFID could help to reduce stock outs and thus reduce lost sales. In US alone stock outs costs approximately $30 billion annually (Teresko, 2003).
4. Improved data accuracy: RFID could improve inventory records by reducing human errors and it could also reduce errors in shipment data that could influence demand forecasting. Accuracy in such information could improve retail management decisions.
5. Accuracy, speed and efficiency of processes: RFID could reduce inventory counting time, receiving time, loading / unloading time, and wait time before loading and thus improve operating speed and efficiency (Rutner et al., 2004).
6. Real-time visibility: Retail interest in RFID technology is driven by the desire of companies to achieve greater speed and visibility into their supply chains, with the goal of increasing both operational efficiency and

store effectiveness. RFID allows an efficient supply chain operation ensuring that products are delivered to the place and time when consumers are ready to purchase. Potential gains from the visibility RFID generates include lower inventory levels, reduced labor costs, and increased sales.

7. Reduced inventory: RFID allows products to be followed in real-time across the supply chain providing accurate and detailed information on all items allowing such information to be used to increase efficiency. Thus increased accuracy in such data could reduce stock out situations. RFID could further reduce safety stock requirements by facilitating just-in-time inventory (JIT), and automatic replenishment (Prater et al., 2005).
8. Increased sales: RFID could increase overall retail sales by reducing stock outs and enhancing customer services.
9. Business intelligence: RFID has a positive and significant impact on business intelligence. It could provide enterprises with the opportunity of gleaning both real-time and decision-support information from a continuous avalanche of product and product-related data.
10. Improved collaboration: RFID improves collaboration between retailers and other supply chain partners because a great deal of detailed and accurate information could be made available for each case of product at each location in the supply chain. Since this data is more detailed and more accurate than the information that is available with other identification technologies like barcodes, the ability to manage demand could improve and all supply chain partners could benefit from that.

11. Improved returns / recall management: RFID has the potential to dramatically change the handling of retail returns. With RFID tagging of individual items, all parties in the returns handling process has far greater visibility and thus could create value from the process. With RFID tagged goods being returned, retailers are able to gain far greater insights into their overall returns processes by tracking returns by product line, manufacturer, store, and even consumer. By sharing this data with consumer goods makers, both parties could better monitor returns processes and gain insights into patterns that may emerge through modeling the data across different regions and stores. Also retailers could supplement the basic shipment identification information of products by recording the specific customer and time of shipment to the tag immediately prior to distribution. Producing and recording this information would provide several benefits. In the event of a recall, retailers could trace specific shipments to specific customers, which would enable a highly targeted notification and return operation and thus avoid a costly general recall.
12. Reduced overall cost: Since RFID tags could be read without requiring to be manually scanned, there can be significant labor savings across various retail operations. Reduced inventory and stock outs made possible by RFID along with reduced theft and shrinkage across retail stores and distribution centers also reduce overall cost.

13. Improved visibility of orders and inventory: RFID allows orders and inventory to be tracked in real time thus reducing safety stock requirements and unnecessary reordering in cases of delayed delivery.
14. Reduced labor requirements / costs: RFID reduces labor requirements in receiving, picking, storing, and distribution contributing to savings that add to the retail revenue.
15. Reduced missing sales: RFID allows for reduced missing sales by allowing for improved on shelf availability of products achieved through reduced stock outs and automatic replenishments policies.
16. Reduced shrinkage: RFID reduces shrinkage that occurs due to various reasons such as misplacement, spoilage, or theft. Shrinkage costs to retailers is estimated to be $30 billion annually and RFID is believed to be able to reduce it by two-thirds (Twist, 2005).
17. Improved asset management: RFID tags attached to fixed assets such as pallets, containers, trailers, and other equipments allows tracking their movement and the information could be used to quickly locate expensive tools or equipments when they are needed.
18. Improved labor productivity: RFID improves worker productivity by eliminating manual intervention and thus reducing errors. It also eliminates the need for manual counting of inventories.
19. Tracking shopping behavior: RFID allows real-time tracking of information about customers shopping behavior based on the kind of

products that they buy or return. Real-time information on overall purchases could allow retailers to make improved business decisions.

20. Tracking temperature: RFID tags allow for tracking and monitoring shocks and temperature levels of products to ensure the quality of the end product.
21. Competitive advantage: RFID provides competitive advantage for retailers by allowing for improved services and lower prices for customers.
22. Monitor worker productivity: RFID could allow for tracking of employee's work location revealing the amount of activity performed. This further increases worker productivity by providing employees incentives to work more efficiently and effectively.

4.1.2. Content analysis of RFID applicable business processes

Starting with the entire set of RFID related articles, 931 instances were observed that mention one or more RFID applicable business processes specifically for retail. Table 4-3 shows the frequency and percentage of articles corresponding to each business process that could be influenced by RFID technology. The most important business processes are tracking / tracing, replenishing, receiving, checkout, and demand forecasting followed by reuse and recycle / returns, shipping, picking, ordering, transport, and storing. These processes are crucial for overall retail operations.

Table 4-3. RFID applicable business processes

Business Processes	Frequency	Percentage
Tracking/Tracing	207	22.23%
Replenishing	195	20.95%
Receiving	122	13.10%
Checkout	94	10.10%
Demand forecasting	92	9.88%
Re-use and recycle/Returns	81	8.70%
Shipping	68	7.30%
Picking	30	81.42%
Ordering	20	2.15%
Transport	12	1.29%
Storing	10	1.07%
Total	931	100%

The identified business processes and their RFID applicability are briefly discussed below:

1. Tracking and tracing: It refers to the identification of products across their movement through the supply chain. It also pertains to tracking temperature and pressure conditions of products while in transit. RFID allows continuous tracking of products in transit across the supply chain thus allowing for making various business decisions including replenishment and ordering.
2. Replenishing: With the inherent capability of RFID to track inventory in real-time, it allows shelf replenishment process to be more efficient and effective. This capability to smartly replenish store shelves from backroom inventory may reduce out of stock situations and lost sales significantly. It also reduces overstock requirements.

3. Receiving: It refers to receiving of products in warehouse facilities or in stores. RFID allows significant improvements in the speed and accuracy of receiving products by eliminating the need to manually scan each shipment product. RFID scanner reads the shipment as it passes through the portal reader within seconds. Additionally, it eliminates the need to physically check the packing slip and allows to automatically checking if a product needs a cross-dock movement to fill an open order.
4. Checkout: RFID scanning of all products at the point of sales (POS) enables the store to implement an automated inventory process that independently recognizes each product sold. Additionally with RFID, goods scanned at the POS require no human intervention as they pass within a certain distance of a reader. This makes the checkout process faster for the customer and more efficient for the retailer, who can deploy employees to other activities that could enhance customer service.
5. Demand forecasting: It refers to better demand planning and improved collaboration due to higher levels of visibility of products throughout the supply chain and acquisition of business information about consumer behavior and their reactions to products.
6. Re-use and recycle / returns: It refers to better and faster handling of returns of products and reuse of fixed assets like pallets, containers, or other equipments.
7. Shipping: An RFID system can confirm that each item is placed onto the correct outbound vehicle that is verified, as the product moves through the

portal of the outbound dock door and thus improving the accuracy of the shipping process.

8. Picking: RFID system allows correct items and products to be picked from the facility. It also allows to measure productivity in the facility. Elimination of manual scan of products makes the picking process more efficient and faster.
9. Ordering: RFID tags attached to items enable the store to check its inventory levels quickly and effectively. The system allows seeing discrepancies between the items on the shelves and the store inventory that could then be noted and reported. After checking inventory levels in store, the system could generate an order and check it against the supply chain for any likely problems. It makes the ordering process much more efficient reducing possibilities of unnecessary reordering.
10. Transport: RFID could improve the transport process because of the inherent capacity of RFID systems to assist in vehicle identification and tracking / tracing and thereby enhancing both economic efficiency and security. It can reduce occurrences of empty running of trucks and trailers.
11. Storing: It refers to storing products in a warehouse or backroom storage facility. An RFID system eliminates the need to scan the bar code on the pallet and at the slot location in the racks of the facility. If the pallet and slot location read by the RFID scanner do not match, the system notifies that the product is placed in the wrong location. Also, RFID could improve temporary storage at the facility by eliminating the need to store

products and pallets in specific locations since RFID tags can be read from anywhere. Such random location system allows for a much more flexible storage environment.

4.1.3. Content analysis of RFID applicable value chain activities

Most of the major industries today see immense potential in RFID technology to better integrate their value chain that can improve their efficiency and cut down overall cost of operations significantly. Benefits of RFID primarily revolve around allowing for improved value chain management. Real-time visibility made possible by RFID helps to achieve tightly integrated value chain. A typical integrated retail value chain has the following major elements shown in Figure 4-1 (Callana, 2006).

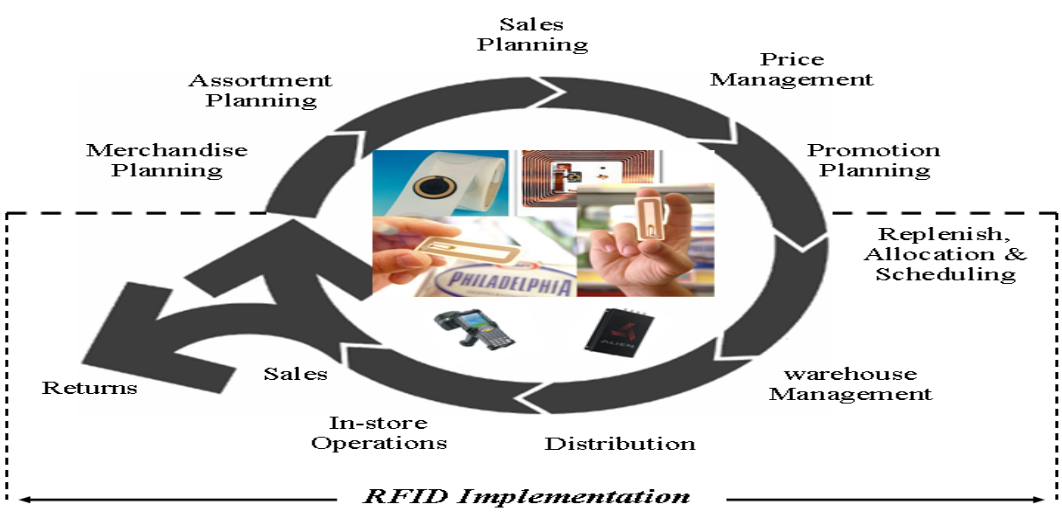


Figure 4-1. Integrated retail value chain (Adapted from Callana, 2006)

Starting with the entire set of RFID related articles, 899 instances were observed that mention one or more RFID applicable value chain activities specifically for retail. Table 4-4 shows the frequency and percentage of articles related to retailers using or considering use of RFID in value chain activities. The most important value chain activities that could be influenced by RFID are replenishment, warehouse management and distribution, in-store operations, sales planning, sales, and returns/recalls followed by promotion and merchandise planning, price management, and assortment planning.

Table 4-4. RFID applicable value chain activities

Value Chain Activities	Frequency	Percentage
Replenish, allocation, and scheduling	195	21.69
Warehouse management and distribution	178	19.80
In-store operations	158	17.58
Sales planning	104	11.57
Sales	82	9.12
Returns / Recalls	81	9.01
Promotion planning	62	6.90
Merchandise planning	23	2.56
Price management	12	1.33
Assortment planning	4	0.44
Total	899	100%

The identified value chain activities are briefly explained below (Vargas, 2007):

1. Merchandise planning: It is an approach aimed at maximizing return of investment (ROI) through proper planning of sales and inventory. This approach is all about maintaining a balance between sales and inventory in order to increase profitability. RFID technology can improve the merchandise planning activity by enabling planning and maintaining a

balance between sales and inventory made possible through greater availability of real-time sales data.

2. Assortment planning: It is the retailers' planning for selection of merchandise both in terms of depth and breadth (e.g., what and how much). Assortment planning activity could be improved by RFID by allowing a better selection of merchandise for a variety of customer needs.
3. Sales planning: It is an activity to plan the routes to reach the target customers. Sales planning activity could be improved by aiding in planning routes to better reach target customers. This is achieved through personalized guidance that can be provided to the valued customers based on the other products that they have purchased in past or are looking at that moment. For example the customer could be prompted to buy some accessories that match with the suit that she is trying or has already purchased.
4. Price management: It is the activity of understanding, managing, and improving pricing processes based on predictions and forecast data. It has direct impacts on profit. The price management activity could be improved by RFID usage through improved pricing decisions based on forecast data generated from real-time information.
5. Promotion planning: It is the activity of planning and managing promotions that drives demand and profit. It also depends on forecast data. RFID technology can allow improved planning of promotions based on real time sales data.

6. Replenishment: It is the activity to replenish products to avoid out-of-stock situation. It has the potential to reduce inventory and improve customer services. RFID improves the replenishment activity by allowing improved management of product delivery thus avoiding out-of-stock situations.
7. Warehouse management and distribution: It is the activity to achieve improved distribution of products across diverse facilities. It has the potential to reduce inventory. RFID has dramatically improved the warehouse management activity by allowing for effective management of inventory and track the location of specific goods within the warehouse.
8. In-store operation: It refers the management of various store operations like receiving, shelf stocking, product ordering for store replenishment etc. RFID technology improves store operations and increases shelf availability by allowing for tracking of goods throughout the facility, including in the back room, on the selling floor, in the fitting rooms, and at the point of sales. This visibility enables retailers to optimize their inventory replenishment, reduce out-of-stocks and on-hand inventory and, ultimately, improve sales.
9. Sales: It refers to the management of the ‘sales’ activity which is directly associated with revenue generation. Sales activity is improved by increasing revenue generation through reduced labor needs for finding products for customers. The employees can rather focus on customer

interaction thus boosting customer satisfaction which is crucial for retailers as it provides a competitive edge.

10. Return / Recall: It refers to management of return merchandise. The idea is to make reverse logistics streamlined. RFID improves the return / recall activity by enabling better management of returned and recalled merchandise through increased visibility. With RFID, companies are able to trace specific shipments to specific customers and enable a targeted recall operation avoiding a costly general recall.

4.1.4. Content analysis of challenges in adopting RFID

Starting with the entire set of RFID related articles, 359 instances are observed that mention one or more RFID adoption challenges for retail. Table 4-5 shows the frequency and percentage of articles corresponding to each of these challenges.

Table 4-5. RFID implementation challenges

Challenges	Frequency	Percentage
Privacy issues	117	32.59
High cost	56	15.60
Technical issues (Readability)	54	15.04
Data warehousing and integration	50	13.93
Lack of standards	37	10.31
Business process redesign	17	4.74
Unclear ROI	13	3.62
Multiple frequencies	7	1.95
Resistance to change	5	1.39
Top management attitude	1	0.28
Lack of technical expertise	1	0.28
Complexity of technology	1	0.28
Total	359	100%

The most important adoption challenges are privacy issues, high cost, technical issues, data warehousing and integration, and lack of standards followed by business process redesign, unclear ROI (return on investment), multiple frequencies, resistance to change, top management attitude, lack of technical expertise, and complexity of technology. The identified adoption challenges are briefly explained below:

1. Privacy issues: A major challenge for RFID adoption in retail is to overcome privacy concerns about the technology coming from consumer groups worried by the possibilities of tracking user behaviors and profiles without any control and awareness. Once an item is tagged it could continue being tracked even after purchase.
2. High cost: RFID technology is expensive and high cost is still a barrier for its adoption. Cost of tags is currently too high to tag at item level. Also RFID system requires significant software and hardware upgrade that contribute to the required upfront huge investment.
3. Technical issues: RFID is a new technology and there are technical issues that still need to be resolved before widespread RFID adoption in retail is a reality. Readability of tags is not 100 percent due to material effect on antenna power pattern, tag antenna orientation, or collision caused by simultaneous radio transmission by several tags in the vicinity. For example a large portion of radio energy is refracted into liquid if UHF radio waves propagate toward liquid and reflected when it passes through metals. If a tag antenna is perpendicular to a reader antenna, the tag cannot receive the reader's radio signal and the tag cannot be read by the reader.

Additionally, if there are obstacles between the two antennas, reading range is reduced. In UHF based RFID applications several tags may respond to a reader's signal and simultaneous transmitted radio signals may cause collision interference to the reader and affect readability of tags.

4. Data warehousing and integration: The sheer volume of real-time data generated by RFID system, the storage and transmission of the data places a severe strain on most retailers' existing IT infrastructure. Also retailers need to integrate the RFID system and the data they generate with backend applications which is a big challenge.
5. Lack of standards: A lack of consensus of standards for data, hardware, and RF (Radio Frequency) operating frequencies is seen as a daunting challenge for RFID adoption. There are concerns about interoperability between RFID systems and legacy systems of organizations.
6. Business process redesign: Benefits of RFID cannot be realized fully without changes in organization practices and business processes.
7. Unclear ROI: Return on investments (ROI) for RFID system is unclear due to lack of clarity surrounding the true costs of RFID hardware and services and payback time being extremely lengthy (Lapide, 2004). Additionally, RFID benefits differ considerably by industry, favoring those with higher product values (Atkearney, 2003).
8. Multiple frequencies: Existing RFID systems may use different frequencies and different countries may have assigned different bands of

the radio spectrum and is a challenge for RFID adoption. It is an important issue that needs to be addressed to avoid future problems. Additionally it is unclear what frequency will ultimately be used at the item level. Some retailers use HF for item level tagging while most retailers use UHF for case and pallet level tagging. Technology vendors also advocate use of HF for item level tagging. In such a situation it might be a bigger challenge to abandon UHF for item level tagging.

9. Resistance to change: Resistance to change by employees is a challenge for RFID adoption like any other new technology. This resistance comes primarily from lack of awareness and proper education on handling the technology.
10. Top management attitude: Lack of awareness about the potentials of RFID among top management who are in decision making positions inhibits the adoption of the technology. It is always a challenge to get top management commitment for adopting a technology that is new to them.
11. Lack of technical expertise: Lack of sufficient numbers of skilled RFID professionals is also an inhibitor for RFID adoption. Training and education of the employees on RFID technology is a major challenge.
12. Complexity of technology: The general complexity of RFID technology involving data management and integration with existing applications and business practices is a major adoption challenge.

With technological advancements, most of these challenges will eventually be overcome. However, being a societal issue, privacy requires more than technological advancement and will remain a major challenge for retailers. A balance between the benefits consumers can get in terms of better service and savings and the impingement on privacy and increased awareness among consumers should be a top priority of retail sector.

4.1.5. Content analysis of technology choice

Technology choice decisions in RFID adoption concern choosing the appropriate radio frequency, tagging level, and tag type. Factors such as, user requirements, product contents (water, metal), application type, reading distance, security concerns, and environmental factors (e.g., noise, vibration, moving speed, and magnetic sources) along with cost considerations determine these decisions. Among these, product content, application type, and cost issues are the major factors for making the decision.

Starting with the entire set of RFID related articles, 139 instances were observed that mention technology choice in terms of frequency level, 303 instances for tagging level, and 126 instances for tag types.

Table 4-6 shows the frequency and percentage of articles corresponding to the available choice of RFID technology in terms of frequency, tag level, and tag type. The content analysis indicates that UHF is the dominant frequency used by retail sector. Around 81% of the articles mentioned use of UHF as the dominant frequency used in retail. The other 14% of the articles claim HF to be used in retail, and about 3% of the articles suggested use of near field UHF, and the rest 1.44% indicated use of LF.

Both pallet and case level tagging came out to be significant, supported by 39% and 34% of articles respectively. Item level tagging is also picking up and is suggested by about 28% of the articles.

Tags can be classified into four types: passive, active, semi-passive, and semi-active. They are different in terms of the availability of power and how they communicate. The selection of tags is also influenced by several factors, for example, cost, read / write capability, size / weight, memory, tag life, power source, and read distance. Among these, cost, write capability, and power source are the key selection factors. Passive tag is the dominant tag type used in retail indicated by about 80% of the articles. The other 18% of the articles indicated use of active tags and the rest 0.79% indicated use of passive dual frequency tags.

Table 4-6. RFID technology choice

Technology Choices	Frequency	Percentage
UHF reader	113	81.29
HF reader	20	14.39
Near field UHF reader	4	2.88
LF reader	2	1.44
Total	139	100
Pallet level tagging	116	38.28
Case level tagging	103	33.99
Item level tagging	84	27.72
Total	303	100
Passive tags	102	80.95
Active tags	23	18.25
Passive dual frequency tags	1	0.79
Total	126	100%

4.2. Descriptive results from Delphi study

4.2.1. Adoption stages

4.2.1.1. Construct measures

The questionnaire for investigating the adapted stage model is developed from statements in the theory of diffusion of innovation (Rogers, 1995). Items were developed to fit the RFID context. A five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree) is used for all items. The dependent variable of retailer's RFID adoption intent is recoded as a dichotomous variable measuring whether the experts disagree or agree with retailers RFID adoption intent. The construct is operationalized via a five-point Likert scale which is later recoded as disagree and agree. Table 4-7 summarizes the measurement items of the independent variables.

Table 4-7. Measurement items of adoption stage independent variables

Variables	Measurement Items
Knowledge	Technical information about RFID contributes to RFID knowledge
	Information about current RFID adoption status contributes to RFID knowledge
Persuasion	Information about RFID adoption drivers contributes to persuasion
	Information about RFID benefits contributes persuasion
Design and decision	Information about RFID applicable business processes contributes to RFID design and decision
	Information about RFID applicable value chain activities contributes to RFID design and decision
	Information about RFID technology choice contributes to RFID design and decision
Implementation	Information about RFID adoption challenges contributes to implementation
	Information about RFID adoption diffusion strategy contributes to implementation

4.2.1.2. Reliability and validity analysis

Validity is assessed through content validity and is established through an extensive process of item selection and further refinement. The items are then scrutinized by a team of researchers including faculty and graduate students to ensure that they measure the appropriate domain of the construct.

The reliability of the constructs is assessed using Cronbach's alpha. The reliability properties of the measurement constructs are given in table 4-8. The results in table 4-8 indicate all of the constructs have adequate alpha values (> 0.7).

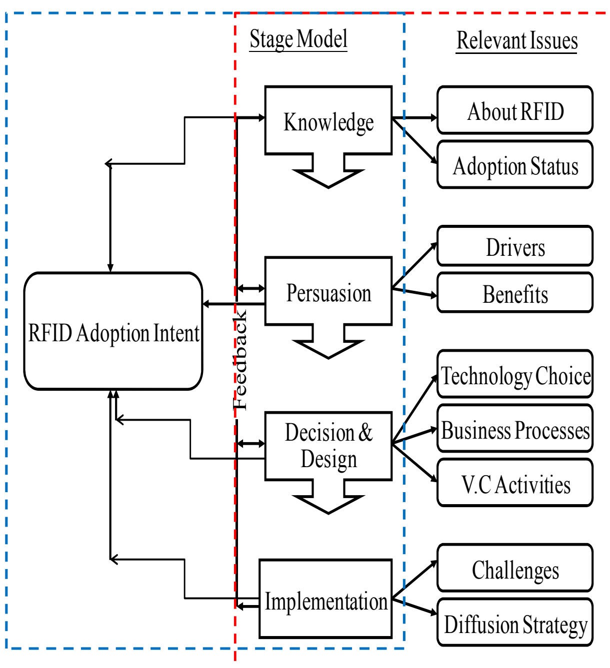
Table 4-8. Validity and reliability properties of adoption stages

Variables	No. of Items	Alpha-Value
Knowledge	2	0.777
Persuasion	2	0.806
Design and decision	3	0.746
Implementation	2	0.700

4.2.1.3. Research model and propositions

The four stages of RFID adoption adapted from Rogers' diffusion of innovation theory are knowledge, persuasion, design and decision, and implementation as specified in Figure 4-2. The adapted stage model serves as the foundation of the conceptual framework of the impact of RFID that is developed in this study.

Basically, the conceptual framework of the impact of RFID suggests factors and variables that enhance adoption and diffusion of RFID. It is hard to validate the stage model empirically since it requires probing the interpersonal mental process of a respondent (expert). However there is tentative empirical evidence of the validity of stages in innovation decision process (Beal and Rogers, 1960) with more clear-cut evidence for the knowledge and decision stages and somewhat less for the persuasion stage. Although the stage concept is very important in diffusion research, less research has been directed to understand it because the nature of the research topic does not fit the quantitative research methods most commonly used by diffusion researchers (Rogers, 1995). Figure 4-2 represents the stage model along with the proposed hypotheses that serves as the building block of the RFID impact framework.



#	Propositions
1a	Information about RFID technical aspects and current adoption status influences RFID knowledge
1b	RFID knowledge influences its adoption
2a	Information about RFID adoption drivers and benefits influences RFID persuasion
2b	RFID persuasion influences its adoption
3a	Information about RFID applicable business processes, value chain activities, and choice of technology influence RFID design and decision
3b	RFID design and decision influences its adoption
4a	Information about RFID adoption challenges and diffusion strategy influences RFID implementation
4b	RFID implementation influences its adoption

Figure 4-2. Proposed RFID stage model and hypotheses

The stage model suggests that innovation knowledge explains the degree of knowledge in the field of the particular innovation that an adopter or potential adopter has acquired from theory and practice.

Basic, technical and technological knowledge, along with knowledge about current innovation adoption status (what peers are doing) is important for the adoption of the innovation. Innovation knowledge is expected to contribute to forming persuasive attitude, decision making activities, and putting the innovation to use. The knowledge stage involves general awareness knowledge, "how to" knowledge, and principle knowledge (Rogers, 1995). Awareness knowledge involves information that the new innovation exists and the information about the current status of adoption of the innovation. The general awareness knowledge about the technology then motivates to seek "how to" knowledge that consists of information necessary to use the innovation appropriately. The awareness knowledge further motivates to seek principle knowledge about the new innovation that consists of information dealing with the functioning principles underlying the new innovation.

The propositions that follow are therefore:

Proposition 4-1a: Information about RFID technical aspects and current adoption status influences RFID knowledge.

Proposition 4-1b: RFID knowledge influences its adoption.

Next, in the stage model is the persuasion stage where the decision making unit that could be an individual or a firm forms a favorable or unfavorable attitude toward a new innovation. The decision making unit forms a general perception of the innovation. In developing the attitude toward the new innovation, "the decision making unit mentally applies the new idea to his or her present or anticipated future situation before deciding about trying it" (Rogers, 1995, pp168). This stage involves a lot of forward planning about the innovation and is thus futuristic.

The propositions that follow are therefore:

Proposition 4-2a: Information about RFID adoption drivers and benefits influences RFID persuasion (forming positive or negative attitude).

Proposition 4-2b: RFID persuasion influences its adoption.

Next, is the design and decision stage. The design and decision stage occurs when the decision making unit engages in activities that lead to a choice to adopt or reject the new innovation. The decision to adopt RFID technology is made to make full use of the innovation as the best course of action that is currently available. The decision to reject it is made if the decision making unit is not convinced about the innovation. Before making such a decision about a new innovation, the decision making unit usually tries it out on a smaller scale in order to determine its usefulness in their specific situation and context. Also, the decision making unit could be informed by the trial of the innovation by a peer like themselves.

The propositions that follow are therefore:

Proposition 4-3a: Information about RFID applicable business processes, value chain activities, and choice of technology (frequency, tagging level, and tag type) influence RFID design and decision.

Proposition 4-3b: RFID design and decision influences its adoption.

The last stage in the stage model is the implementation stage that occurs when the decision making unit puts an innovation into use. At this stage the innovation is put into real practice. Problems in exactly how to effectively put the innovation to use comes up at the implementation stage. Even after the decision to adopt the new innovation is made at the decision stage, uncertainty about the consequences and challenges of the innovation still exists. It involves operational problems that gradually come up after the innovation is put to use. The implementation stage continues till the new innovation becomes an institutionalized practice in the organization that has adopted the technology.

The propositions that follow are therefore:

Proposition 4-4a: Information about RFID adoption challenges and diffusion strategy influences RFID implementation.

Proposition 4-4b: RFID implementation influences its adoption.

4.2.1.4. Data analysis and findings

The composite scores of the four factors were calculated by averaging the original items scores. Table 4-9 shows the four adoption stages as identified by the experts and represented by the rating average (mean), standard deviation of the responses, and results of 1 sample t tests in terms of t test statistics, 95% lower bound of the confidence interval, and the p-values. The one sample t tests are performed to verify agreement (The alternative hypotheses are H_{ai}: $\mu_i > 3$). The means are compared with 3 because in a scale of 1-5, 3 indicates agreement.

Table 4-9. RFID adoption stages

Adoption Stages	Rating Average (Mean)	Std. Deviation	H_{ai}: μi > 3		
			T statistic	95% Lower Bound	P-Value
Knowledge	3.67	0.70	8.23	3.53	0.000
Persuasion	3.82	0.67	10.53	3.69	0.000
Design and decision	3.68	0.64	9.14	3.56	0.000
Implementation	3.75	0.66	9.78	3.62	0.000

From table 4-9 it is observed that the mean score for RFID technical information contributing to general knowledge about the technology involving awareness, “how to”, and principle knowledge about the technology and adoption status is 3.67 and the 95% lower bound is 3.53 which on a scale of 1-5 indicates agreement that such information accrues to building knowledge about RFID technology. Overall, general information about RFID and current adoption status influences RFID knowledge, providing support for proposition 4-1a.

Mean score for information about RFID adoption drivers and benefits contributing toward persuasion is 3.82 and the 95% lower bound is 3.69 indicating agreement that such information influences persuasion providing support for proposition 4-2a.

Mean score for information about RFID applicable business processes and value chain activities, and technology choice contributing toward design and decision are 3.68 and the 95% lower bound is 3.56 indicating agreement that such information influences design and decision providing support for proposition 4-3a.

Finally, mean score for information about RFID adoption challenges and diffusion strategy contributing toward implementation are 3.75 and the 95% lower bound is 3.62 indicating agreement that such information influences implementation providing support for proposition 4-4a. Table 4-10 below shows the results in summarized form.

Table 4-10. Summary results

Variables	Propositions	Results
Knowledge	4-1a: Information about RFID technical aspects and current adoption status influences RFID knowledge	Accepted
Persuasion	4-2a: Information about RFID adoption drivers and benefits influences RFID persuasion (forming positive or negative attitude)	Accepted
Design and decision	4-3a: Information about RFID applicable business processes, value chain activities, and choice of technology (frequency, tagging level, and tag type) influence RFID design and decision	Accepted
Implementation	4-4a: Information about RFID adoption challenges and diffusion strategy influences RFID implementation	Accepted

In order to test for propositions 4-1b, 4-2b, 4-3b, and 4-4b, multivariate discriminant analysis (MDA) is used. It provides a statistical procedure to identify the variables that best discriminate between adopter and non-adopters. It is a more powerful and robust statistical procedure that provides a multivariate estimation of comparing means of variables in two groups independently. The objective of the analysis is to maximize between-group variances relative to within-group variance.

To test the model, all four independent variables are entered in one step to generate the discriminant function. However, discriminant analysis assumes homogeneity of co-variances which is examined with Box's test of equality of co-variances. The null hypothesis for Box's test is that the variances of the independents among categories of the categorical dependent are not homogenous. The value of Box's M, F-value, and the level of significance of the test are 19.241, 1.72, and 0.071 respectively. Since the significance level is close to cut off value of 0.10 and the sample size for the test is quite large the log determinant values of the group covariance matrices are observed. The log determinant values for adopter, non-adopter, and pooled within-group are -3.681, -5.727, and -4.895 respectively. Since the group log determinants are similar, Box's M test results can be ignored and discriminant analysis could be performed (Hair et al., 1983). Discriminant analysis is also sensitive to multicollinearity. A check on multicollinearity is looking at the pooled within-groups correlation matrix. When assessing the correlation matrix for multicollinearity a rule of thumb is that no r (correlation value) > 0.90 and not several > 0.80. Table 4-11 below provides the pooled correlation matrices. Looking at table 4-11, all correlation values are < 0.66 and thus there is no support for the existence of multicollinearity in these independent variables. So, discriminant analysis can be performed.

Table 4-11. Pooled within-groups matrices

		Knowledge	**Persuasion**	**Design and decision**	**Implementation**
Correlation	Knowledge phase total	1.000	.651	.596	.457
	Persuasion phase total	.651	1.000	.535	.410
	Design phase total	.596	.535	1.000	.535
	Implementation phase total	.457	.410	.535	1.000

Discriminant model is generated for RFID adoption intent of retailers. The value of Wilk's Lambda, chi-square value, and the level of significance is shown in table 4-12. The model is significant with p-value = 0.014 at 10% significance level. The standardized discriminant coefficients and discriminant loadings for the variables are also provided in table 4-12. Univariate statistics in terms of group-wise means and F-value significance on equality of means are provided for comparative analysis. Discriminant loadings (Structural correlation), measuring the simple linear correlation between each predictor variables and the extracted discriminant function, is used to determine the significance of the variables. The general guideline is that the values above 0.3 are satisfactory and acceptable (Hair et al., 1983).

Table 4-12. Discriminant analysis – Adoption stages

Wilk's Lambda = 0.644, Chi-Square = 22.84, DF = 10, Sig = 0.011					
Variables	**Discriminant Coefficients**	**Discriminant Loadings**	**Univariate Analysis Group Mean (S.D)**		
			Adopter	**Non-adopter**	**Sig**
Knowledge	0.022	0.574	3.91 (0.626)	3.50 (0.730)	0.033
Persuasion	-0.166	0.441	4.02 (0.649)	3.69 (0.793)	0.099
Design and decision	0.807	0.941	3.85 (0.665)	3.19 (0.544)	0.001
Implementation	0.392	0.392	4.02 (0.537)	3.50 (0.816)	0.005

The significant variables thus are knowledge, persuasion, design and decision, and implementation. The discriminant loadings of the four significant variables carry positive values. This indicates that the RFID adoption supporters pay more attention than the non-adoption supporters on all of the four variables. The univariate significance levels corresponding to the F statistics given in table 4-12 also indicate that these variables were significant independently as well.

Classificatory test is done to determine the ability of the model to classify accurately. The classification result is used to assess how well the discriminant function works, and whether it works equally well for each group of the dependent variable.

Classification result is provided in table 4-13. From table 4-13 it is observed that the classificatory ability of the discriminant model is 77.4% for the original grouped cases and 69.4% for the cross-validated cases where each case is classified by the functions derived from all cases other than that case.

Table 4-13. Classification result

		Retailers RFID Adoption Intent	Predicted Group Membership		Total
			Non-adopter	Adopter	
Original	Count	Non-adopter	4	12	16
		Adopter	2	44	46
	%	Non-adopter	25.0	75.0	100.0
		Adopter	4.3	95.7	100.0
Cross-validated[a]	Count	Non-adopter	3	13	16
		Adopter	6	40	46
	%	Non-adopter	18.8	81.3	100.0
		Adopter	13.0	87.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 77.4% of original grouped cases correctly classified.

c. 69.4% of cross-validated grouped cases correctly classified.

Looking at the discriminant coefficients given in table 4-12 it is observed that the variables knowledge design and decision, and implementation positively influences RFID adoption whereas the variable persuasion negatively influences the adoption decision. This is in contradiction to what was expected. The argument for such negative association that is observed is explained by the fact that the established benefits and adoption drivers are not discussed in the context of a particular business domain like retail. As such, the decision making unit finds those information overwhelming and cannot put them in their own specific context and situation. As expected, it is observed that general information about RFID (knowledge); applicable business processes and value chain activities, and choice of technology (persuasion); and challenges and diffusion strategy (implementation) positively influence RFID adoption. Table 4-14 presents the results of the discriminant model in a summarized form.

Table 4-14. Summary results of significant variables

Variables	Propositions	Results
Knowledge	Proposition 4-1b: RFID knowledge positively influences its adoption	Accepted
Persuasion	Proposition 4-2b: RFID persuasion positively influences its adoption	Accepted
Design and decision	Proposition 4-3b: RFID design and decision positively influences its adoption	Accepted
Implementation	Proposition 4-4b: RFID implementation positively influences its adoption	Accepted

4.2.2. Construct measures

The variables of the research model are measured using multi-item indicators. The items are measured using a five point Likert-scale ranging from strongly disagree (1) to strongly agree (5). The principal construct measures are mainly based on content analysis results and statements from relevant literature for the exploratory phase of this research. Items for the current RFID adoption status, RFID benefits, RFID applicable business processes, challenges, choice of technology (in terms of frequency levels, tagging level, and tag type), and diffusion strategy are adapted from content analysis results. Ten items pertaining to RFID applicable value chain activities are adapted from (Callana, 2006).

The measures for business value of RFID are adapted from (Mooney et al., 1996). The questionnaire containing the items for measurement is provided in Appendix B.

4.2.3. Reliability and validity analysis

The constructs are tested for two psychometric properties, validity and reliability, to ensure that the measurement is accurate. Validity assesses the degree to which the items measure the construct, whereas reliability assesses the stability of the scale based on the assessment of the internal consistency of the items measuring the construct (Churchill, 1979). Validity is assessed through content validity which assesses if the measurement covers the complete domain of the construct. It is established through an extensive process of item selection followed by refinement. The items are then scrutinized by a team of researchers to ensure that they measure the appropriate domain of the construct.

The reliability of the constructs is assessed using Cronbach's alpha. Determination of Cronbach's alpha coefficient of internal consistency is to ensure that the items comprising factors produced a reliable scale. A higher score indicates a greater reliability with a range from 0-1. The general agreed upon lower limit of Cronbach's alpha is 0.7 (Nunnally and Bernstein, 1994). However for exploratory research 0.6 is considered to be a reasonable value (Premkumar and Roberts, 1999).

The reliability properties of the measurement constructs are given in table 4-15. The results in table 4-15 indicate most of the constructs have adequate alpha values (> 0.7), except for adoption status, technology choice, and diffusion strategy. The low values could be attributed to using fewer items for measuring the variables since alpha values are sensitive to the number of items used to measure a construct. For the technology choice variable the low value could be because it covers three different aspects (frequency, tag level, and tag type). An alternative approach to evaluate reliability is to assess inter-item correlation. The correlation coefficients between the items measuring adoption status, technology choice, and diffusion strategy are not significant. However since this is an exploratory research and the particular questions corresponding to these variables are open ended in nature, it is not sensitive to the reliability. Also, the items corresponding to these variables need to be further refined in future research.

Table 4-15. Validity and reliability properties

Variables	No. of Items	Alpha-Value
Adoption status	3	0.438
Benefit	22	0.927
Business value	3	0.604
Business processes	11	0.916
Value chain activities	10	0.921
Challenges	12	0.794
Technology choice	10	0.456
Diffusion strategy	2	-0.247

4.2.4. Current RFID adoption status in retail: Knowledge stage

Retail is the second largest sector in terms of the number of employees as well as the number of establishments for doing business in the United States (Vargas, 2007). Increasing globalization has increased retailer competition, thus motivating companies to attain better performance (Koh et al., 2006). Retailers see RFID technology as one potential means of staying competitive and achieving profitability both in the short as well as the long term (Wamba et al., 2006).

According to IDTechEx (2006), the retail sector will comprise 44% of the global RFID market value for systems including tags by the year 2016. So far a few large retailers including Wal-Mart, Metro, and Tesco deploy RFID at case and pallet level. Although item-level tagging is the ultimate goal, none of these retailers have still committed to using RFID at this level. Metro was the first to begin RFID roll outs in November 2004 with 20 partners at the pallet level and by 2006 expected to receive RFID tagged shipments from about 300 suppliers covering about 60-80% of sales (RFID Journal, 2004). Wal-Mart roll out started in January 2005 with its top 100 suppliers at the case and pallet level simultaneously. By January 2006 another 200 suppliers started shipping RFID-tagged cases and pallets to Wal-Mart. Initial process change that Wal-Mart expected to realize was automatic generation of picking lists for store employees for those products available in the backroom (RFID Journal, 2005). Metro begun RFID roll out by the end of the year 2004 to track shipments from its central distribution center to 98 of its stores. Tesco stores in UK (RFID Journal, 2004) also rolled out RFID internally to track reusable trays as part of their secure supply chain initiative (RFID Journal, 2004).

Despite all the early uproar about going RFID, the adoption of the technology in retail has slowed down. This demands the need to investigate the perceived RFID adoption status by experts in the area.

From the Delphi study, the experts' perception about the current status of RFID adoption in retail sector is captured. According to the experts complying with trading partner requests or government mandates (slap and ship approach) is where the RFID adoption status currently lies. Next, is the optimization achieved by improved efficiencies of current processes within the retail organization (comprising the value chain). Finally, experts also pointed that RFID adoption status is approaching the level of transformation achieved when new processes and applications come up due to RFID capabilities. All the three conditions representing current RFID adoption status in retail are perceived to be closely important.

Table 4-16 below depicts experts' opinion about current RFID adoption status represented by the rating average of their responses, standard deviation, and 95% lower bounds of the confidence intervals (One sample t test results). The one sample t tests are performed to verify agreement (The alternative hypotheses are H_{ai}: $\mu_i > 3$). The means are compared with 3 because in a scale of 1-5, 3 indicates agreement.

However, looking at the specific numbers it is observed that slap and ship still represents RFID adoption followed by optimization and transformation. However transformation is where the real benefit of RFID is expected to be realized.

Table 4-16. Current RFID adoption status in retail

Adoption Status	Rating Average (Mean)	Std. Deviation	(H_{ai}: $\mu_i > 3$) 95% Lower Bound
Slap and ship	3.73	0.917	3.55
Optimization	3.67	0.914	3.49
Transformation	3.62	0.995	3.43

4.2.5. Retailer benefits of adopting RFID: Persuasion stage

Table 4-17 shows the key RFID benefits for retailers as perceived by the experts represented by the rating average (mean) of their responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). Improved data accuracy, reduced out of stock, reduced shrinkage, reduced missing sales, and real time visibility are the most important benefits that could be obtained through RFID implementation.

Table 4-17. RFID benefits

Benefits	Rating Average (Mean)	Std. Deviation	(H_{ai}: $\mu_i > 3$) 95% Lower Bound
Improved data accuracy	4.44	0.707	4.300
Reduced out of stock	4.36	0.674	4.230
Reduced shrinkage	4.16	0.746	4.015
Reduced missing sales	4.18	0.855	4.014
Real-time visibility	4.18	0.887	4.008
Improved visibility of orders and inventory	4.15	0.855	3.984
Reduced inventory	4.11	0.859	3.944
Accuracy, speed and efficiency of process	4.08	0.777	3.930
Business Intelligence	4.04	0.789	3.887
Improved asset management	4.01	0.790	3.857
Improved customer service levels	3.99	0.858	3.824
Security against theft/fraud/loss/counterfeiting	3.87	0.765	3.722
Improved collaboration	3.83	0.822	3.671
Competitive advantage	3.82	0.827	3.660
Tracking temperature	3.76	0.911	3.583
Improved returns/recall management	3.75	0.960	3.564
Improved labor productivity	3.74	0.978	3.550
Reduced overall cost	3.73	0.990	3.538
Increased Sales	3.73	1.070	3.523
Reduced labor requirements/costs	3.54	1.034	3.340
Tracking shopping behavior	3.45	1.106	3.236
Monitor worker productivity	3.25	0.954	3.065

Factor analysis of the initial 22 items of RFID benefits reveals five factors with Eigen-values above 1.0 that account for about 70% of the total variance. Potential benefits of RFID consists of (a) improved operational efficiency, (b) improved inventory management, (c) improved customer, supplier coordination, (d) improved visibility, and (e) improved security. Specific factor loadings are shown in table 4-18.

The data indicates that the experts regard improved operational efficiency as the most important benefit of RFID for retailers followed by improved inventory management, and improved customer, supplier coordination, improved visibility, and improved security. These potential benefits have automational, informational, or transformational effects as developed in the theory of business value of IT (Dedrick et al., 2003; Mooney et al., 1996).

Table 4-18. Factor analysis of RFID benefits

Factors and Items	Factor Loadings	Eigen-Value	% of Variance
Improved operational efficiency (α= 0.883) (Automational)		3.933	17.876
- Reduced labor costs	0.830		
- Improved labor productivity	0.744		
- Accuracy, speed, and efficiency of processes	0.695		
- Reduced overall cost of operations	0.623		
- Competitive advantage	0.603		
- Improved customer service levels	0.518		
Improved inventory management (α= 0.848) (Informational)		3.862	17.556
- Reduced missing sales	0.858		
- Reduced out of stock	0.852		
- Reduced inventory	0.721		
- Increased sales	0.619		
- Business intelligence	0.457		
Improved customer, supplier coordination (α= 0.818) (Informational)		3.027	13.757
- Tracking temperature	0.754		
- Tracking shopping behavior	0.666		
- Improved returns/recall management	0.656		
- Improved collaboration	0.603		
- Monitor worker productivity	0.597		
Improved visibility (α= 0.786) (Informational / Transformational)		2.651	12.051
- Improved order visibility	0.800		
- Real-time visibility	0.745		
- Improved data accuracy	0.543		
- Improved asset management	0.489		
Improved security (α= 0.616) (Informational)		1.924	8.745
- Reduced theft/fraud/loss/counterfeiting	0.845		
- Reduced shrinkage	0.669		

From table 4-18, it is observed that improved operational efficiency is an automational effect that can be achieved by automating operational processes and thus reducing manual intervention and thus errors. Similarly, improved inventory management is an informational effect that can be achieved by improving capabilities to collect, store, process, and disseminate information. Improved customer, supplier coordination is achieved through readily accessible business information in real-time and is an informational effect of RFID. Improved visibility is both an informational and transformational effect. It improves the informational capabilities of retailers and at the same time facilitates new process engineering through real time data capture. Finally, improved security is an informational effect that can be achieved through improved information capture and sharing using RFID, thus reducing thefts and frauds. Currently informational effect is the most important benefit of RFID. However transformational effect is where the real potential exists.

4.2.6. Business value of RFID in retail

After the significant benefits of RFID in retail are identified, the expert's perceptions about the value dimensions of those benefits are investigated. However it is to be noted here that these dimensions or effects are not mutually exclusive. From table 4-18 it is observed that most of the RFID benefits are informational in nature. Table 4-19 below shows the results of the Delphi study represented by the rating average (mean) of their responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). Informational effect is the most important business value of

RFID, followed by transformational, and automational. This is similar to what is observed in table 4-18. However transformational effect is where the true revolutionizing capability of RFID lies and retailers must try to achieve it to gain more from the technology.

Table 4-19. Dimensions of RFID business value

Business Value of RFID	Rating Average (Mean)	Std. Deviation	($H_{\mu i}$: $\mu_i > 3$) 95% Lower Bound
Informational	4.22	0.768	4.071
Transformational	3.95	0.848	3.786
Automational	3.40	0.893	3.227

4.2.7. RFID applicable business processes: Design and decision stage

Table 4-20 shows the 11 retail business processes that are significantly improved by the use of RFID represented by the rating average (mean) of the expert's responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). However these business processes are not exclusive to retail.

It is observed that receiving is one of the most important business processes for retailers that could be improved by the use of RFID. The other important business processes that could be improved are tracking and tracing, replenishing, picking, and shipping. Next, are checkout, storing, reuse and recycle / returns, demand forecasting, ordering, and transport. Use of RFID for the receiving, picking, shipping, and storing allows reducing manual intervention from employees and thus reduces errors. Reducing such errors can then reduce stock out situations which is a big problem for retailers.

Table 4-20. RFID applicable business processes

Business Processes	Rating Average (Mean)	Std. Deviation	($H_{\mu i}$: $\mu_i > 3$) 95% Lower Bound
Receiving	4.40	0.618	4.280
Tracking and tracing	4.30	0.771	4.151
Replenishing	4.25	0.813	4.092
Picking	4.10	0.836	3.938
Shipping	4.05	0.797	3.895
Checkout	4.01	1.028	3.811
Storing	3.81	0.917	3.632
Re-use and recycle/Returns	3.76	0.911	3.583
Transport	3.74	0.913	3.563
Demand forecasting	3.68	0.984	3.489
Ordering	3.68	0.998	3.487

Use of RFID for tracking and tracing of products across the value chain provides retailers with accurate information about the whereabouts of products in real time and thus save them money from reordering of products which are delayed but are on the way. This is an informational benefit for the retailers. RFID can also improve the replenishing process by allowing for just in time inventory (JIT) thus leading to reduced inventory and also reduced out of stock situations. It also eliminates the need for physical inventory counts. This can again lead to a huge cost savings for retailers. RFID can allow for automatic checkout by customers and thus reduce the requirement of labors to facilitate the checkout process. This could improve customer service since the customers can save a lot of their time standing in checkout queues.

RFID can facilitate reuse and recycle / returns process significantly. By the use of RFID, managing reusable assets like crates and containers can be made simple and streamlined. This could lead to reduced loss of resources and thus lead to savings in long term. The technology can also improve the returns process by allowing retailers to gain far greater insights into their overall returns process through instant access to purchase data. They can track the returns by manufacturers, stores, dates of sales, and consumers. They can share these data with CPG (Consumer Product Goods) makers and thus both parties can better monitor returns processes and gain insights into patterns that may emerge through processing the data across regions and retailers.

RFID can improve the transport process by allowing visibility into the location of the trailers and the cargo they contain, and also offering status alerts in the event that a trailer is opened while in transit.

RFID also improves the demand planning process by allowing retailers to respond to consumer demand fast and also marketing to consumers in stores with a fast and responsive value chain. With such timely information, on shelf availability of products is improved tremendously which can then increase customer satisfaction.

Finally, the ordering process is improved by RFID by allowing for an informative ordering of products through the 'right now' ability to see what is truly in stock thus enabling a rapid reaction to inventory demand and current stock levels. From table 4-20 it is observed that most of the business processes that the experts think will be improved through RFID usage revolve around providing for benefits that could be achieved through the automational effect of the technology (less manual intervention). However the real potential of the technology is the transformational effect which could be achieved when

RFID triggers new business processes to be created that could change the way retailers do business today.

Factor analysis of the initial 11 items of RFID applicable business processes reveals a single factor with Eigen-value above 1.0 that account for about 56% of the total variance. Specific factor loadings are shown in table 4-21.

Table 4-21. Factor analysis of RFID applicable business processes

Factors and Items	Factor Loadings	Eigen-Value	% of Variance
RFID applicable business processes		6.058	55.069
- Picking	0.808		
- Ordering	0.808		
- Transport	0.792		
- Demand forecasting	0.789		
- Shipping	0.781		
- Storing	0.758		
- Checkout	0.719		
- Replenishing	0.697		
- Reuse and recycle / Returns	0.683		
- Tracking and tracing	0.661		
- Receiving	0.643		

4.2.8. RFID applicable value chain activities: Design and decision stage

Table 4-22 below shows the value chain activities that are significantly improved by RFID represented by the rating average (mean) of the expert's responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). According to the Delphi study results, improvement in in-store operations is the most important RFID applicable value chain activity. The other important value chain activities that could be enhanced by RFID usage are replenish and scheduling, warehouse management, returns / recalls, and sales followed by promotion, merchandise, sales, and assortment planning, and finally price management.

Table 4-22. RFID applicable value chain activities

Value Chain Activities	Rating Average (Mean)	Std. Deviation	($H_{\mu i}$: $\mu_i > 3$) 95% Lower Bound
In-store operations	4.38	0.700	4.244
Replenish, allocation, and scheduling	4.23	0.773	4.080
Warehouse management and distribution	4.15	0.833	3.989
Returns/ Recall	3.84	0.882	3.669
Sales	3.75	0.954	3.565
Promotion planning	3.75	0.997	3.557
Merchandise planning	3.71	0.920	3.532
Sales planning	3.57	0.870	3.401
Assortment planning	3.56	1.093	3.348
Price management	3.52	1.015	3.323

RFID technology improves store operations and increases shelf availability by allowing for tracking of goods throughout the facility, including in the back room, on the selling floor, in the fitting rooms, and at the point of sale. This visibility enables retailers to optimize their inventory replenishment, reduce out-of-stocks and on-hand inventory and, ultimately, improve sales. RFID improves the replenishment activity by allowing improved management of product delivery thus avoiding out-of-stock situations. RFID has dramatically improved the warehouse management activity by allowing for effective management of inventory and track the location of specific goods within the warehouse.

RFID also improves the returns / recalls activity by enabling better management of return merchandise. Sales activity is improved by increasing revenue generation through reduced labor needs for finding products for customers. The employees can rather focus on customer interaction thus boosting customer satisfaction which is crucial for retailers as it provides a competitive edge.

RFID can also improve retail planning activities. The technology can allow improved planning of promotions based on real time sales data. It can also improve the merchandise planning activity by enabling planning and maintaining a balance between sales and inventory. Sales planning activity could be improved by aiding in planning routes to better reach target customers. This is achieved through personalized guidance that can be provided to the valued customers based on previous purchases. Assortment planning activity could be improved by allowing a better selection of merchandise based on real-time purchase data. Finally, the price management activity could be improved through improved pricing decisions based on forecast data generated from real-time information which is more accurate. All of this is possible through the real time visibility that RFID provides to the retailers.

The experts perceive the planning activities to be potentially improved through RFID usage. However in reality most retailers are focusing on the most obvious activities at the bottom end of the value chain such as in-store operations, replenishment, and warehouse management and distribution. The real potential needs retailers to go beyond the obvious and start tapping onto other value chain activities that are on the top end of the value chain. The experts perceive those activities to be almost equally applicable to RFID usage.

Factor analysis of the initial 10 items of RFID applicable value chain activities reveals a single factor with Eigen-value above 1.0 that account for about 60% of the total variance. Specific factor loadings are shown in table 4-23.

Table 4-23. Factor analysis of RFID applicable value chain activities

Factors and Items	Factor Loadings	Eigen-Value	% of Variance
RFID applicable value chain activities		5.903	59.026
- Merchandise planning	0.889		
- Price management	0.851		
- Assortment planning	0.836		
- Sales	0.798		
- Replenishment	0.760		
- Sales planning	0.727		
- Returns / Recall	0.726		
- Warehouse management and distribution	0.715		
- In-store operations	0.690		
- Promotion planning	0.657		

4.2.9. Technology choice: Design and decision stage

Table 4-24 shows the RFID technology choices available to retailers in terms of appropriate radio frequency, tagging level, and tag type as identified by the experts and represented by the rating average (mean) of their responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results).

Table 4-24. RFID technology choices

Technology Choices	Rating Average (Mean)	Std. Deviation	(H_{ai}: $\mu_i > 3$) 95% Lower Bound
UHF reader	4.22	0.992	4.028
Near field UHF reader	3.75	1.034	3.550
HF reader	3.14	0.916	2.963
LF reader	2.25	1.121	2.033
Case level tagging	4.29	0.615	4.171
Pallet level tagging	4.21	0.887	4.038
Item level tagging	3.92	1.156	3.696
Passive tags	4.45	0.733	4.308
Active tags	3.07	1.046	2.867
Passive dual frequency tags	2.96	1.069	2.753

UHF (Ultra high frequency) is clearly the most important frequency for retailers. Case level tagging appears to be the most important for retailers followed by pallet level and item level tagging. Finally, passive tags are identified to be the important tag type for retail applications.

4.2.10. RFID adoption challenges in retail: Implementation stage

Table 4-25 shows the 12 important RFID challenges identified by the experts and represented by the rating average (mean) of their responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). High cost, unclear return on investment (ROI), business process redesign requirements, lack of top management support, and resistance to change are clearly the most important inhibitors of RFID adoption in retail as perceived by the experts.

Table 4-25. RFID adoption challenges

Challenges	Rating Average (Mean)	Std. Deviation	($H_{\mu i}$: $\mu_i > 3$) 95% Lower Bound
High cost	4.03	1.046	3.827
Unclear ROI	3.82	1.159	3.595
Lack of top management support	3.67	0.993	3.478
Business process redesign	3.67	1.014	3.474
Resistance to change	3.32	1.091	3.109
Readability	3.30	1.186	3.070
Lack of technical expertise	3.26	1.179	3.032
Data warehousing and integration	3.12	1.105	2.906
Privacy Issues	3.05	1.177	2.822
Complexity of technology	2.90	1.131	2.681
Lack of Standards	2.75	1.211	2.515
Multiple Frequencies	2.68	1.092	2.468

Technical challenges such as readability and data warehousing and integration issues are also daunting as the amount of data generated by the typical RFID system is enormous and business processes need to be redesigned to generate useful information from the data. Other challenges such as lack of technical expertise, privacy issues, complexity of technology, lack of standards, and multiple frequencies also hinder RFID adoption.

Factor analysis of initial 12 challenge items (from Delphi data) reveals four factors with Eigen-values greater than 1.0 accounting for about 68% of the total variance. These factors are: (a) technical challenges (b) organizational challenges (c) fit challenges (issues that capture the link between RFID processes and the underlying business processes they are intended to support), and (d) business challenges. Specific factor loadings are shown in table 4-26. The data indicates that the experts regard technical and organizational challenges as the most daunting for RFID implementation in retail followed by fit challenges, and business challenges.

Table 4-26. Factor analysis of RFID adoption challenges

Factors and Items	Factor Loadings	Eigen-Value	% of Variance
Technical challenges (α= 0.883) (Technological)		2.786	23.219
- Readability issues	0.784		
- Multiple frequencies	0.768		
- Lack of standards	0.755		
- Unclear ROI	0.607		
- Data warehousing and integration	0.570		
Organizational challenges (α= 0.848) (Organizational)		2.171	18.094
- Employee resistance to change	0.852		
- Lack of top management support	0.845		
- Lack of technical expertise	0.636		
Fit challenges (α= 0.818) (Technological / Organizational)		1.665	13.872
- Business process redesign	0.865		
- Complexity of the technology	0.620		
Business challenges (α= 0.786) (Technological)		1.465	12.207
- Privacy issues	0.781		
- High cost	0.768		

The technical challenges are technological in nature and will gradually fade with technological advancements over time. The organizational factors are similar to the factors identified in the organizational context of the TOE framework: Top management support, IT expertise, organizational size, and organizational readiness. Employee resistance to change reflects lack of organizational readiness; lack of top management support and lack of technical expertise are the same constructs as identified in literature. The fit challenges are both technological and organizational and include business process redesign and complexity.

The business challenges being privacy and high cost issues are inherent challenges of RFID technology that the retailers need to deal with to take advantage of the potentials of the technology. These challenges are technological in nature because with technological advancements cost will come down and privacy issues can be handled with improved security features. However, business challenges have a lot to do with perceptions of businesses and consumers. With technological advancements, most of these challenges will eventually be overcome. However, privacy concerns require more than technological advancement and will remain a major challenge for retailers. Increased awareness among consumers should be a priority for retailers to deal with the privacy issues as an inhibitor of RFID adoption.

4.2.11. Diffusion strategy: Implementation stage

Technology diffusion can be either initiated from top executives and pushing down to the users for a broader application or demanded from the users and seeking administrative support (Rogers, 1995).

The 'top down' is the traditional model where administrative mandates introduce the technology and administrative decisions and perceptions drive adoption and diffusion. An example is the adoption of the 'internet'.

'Bottom up' is the model in which the diffusion of the technology is primarily dependent on the perceptions and decisions of individual users, as in the case of 'wireless technology'.

Table 4-27 shows the RFID diffusion strategy as perceived by the experts and represented by the rating average (mean) of their responses, standard deviation, and the 95% lower bounds of the confidence intervals (One sample t test results). The process of RFID technology diffusion in retail currently appears to be top down, as it is primarily pushed by top managers and executives. The decision of implementation and usage of the technology depends upon the perceptions of the top management. This is similar to the Internet and personal computer (PC) adoption trends back in 1980's. Considering the similarity it would be interesting to see if RFID also follows the *bubble, burst, boom* model of diffusion like that of PC.

Table 4-27. RFID diffusion strategies

Diffusion Strategies	Rating Average (Mean)	Std. Deviation	(H_{ai}: $\mu_i > 3$) 95% Lower Bound
Top down	3.86	0.871	3.69
Bottom up	3.64	0.948	3.46

Because of the newness of the technology, the current technology diffusion process is expected to be top down irrespective of the type of industry. However, this could change with the maturity of the technology. For automotive, chemical, and high priced electronic goods manufacturing companies, looking at the possibilities of benefits obtained from using RFID in their operations and because high cost is not a very big concern for them, and the fact that errors, and rework are significantly reduced, the diffusion model might change in future.

RFID is an emerging wireless technology in which benefits grow with adoption as with the Internet. Most early RFID adopters incur high costs in their RFID implementation. However, with growing and more adoption, the costs of RFID devices will quickly diminish, and that will lead to more benefits and further adoption (Au and Kauffman, 2005). This should be true regardless of the industry type.

4.2.12. Composite conceptual framework of impact of RFID

Figure 4-3 represents the conceptual framework of impact of RFID that is derived in this chapter. The foundation for the integrated framework of the impact of RFID is the stage model comprised of four different stages: knowledge, persuasion, design and decision, and finally implementation adapted from Rogers (1995). Using multivariate discriminant analysis (MDA) it is observed that the variables knowledge, design and decision, and implementation positively influence RFID adoption whereas the variable persuasion negatively influences the adoption decision. This is explained by the lack of enough efforts on positioning the findings about RFID benefits and adoption drivers in the context of a particular business domain that creates uncertainty about the technology.

Overall, general information about RFID including awareness, "how to" knowledge and current adoption status influences RFID knowledge. Information about RFID adoption drivers and benefits influence persuasion. Information about RFID applicable business processes and value chain activities, and technology choice influence design and decision stage of adoption process. Finally, information about RFID adoption challenges and diffusion strategy influence implementation.

Factor analysis of RFID benefits construct reveals five factors named (a) improved operational efficiency, (b) improved inventory management, (c) improved customer, supplier coordination, (d) improved visibility, and (e) improved security. Operation efficiency contributes the most among the five factors closely followed by improved inventory management. These benefit factors have an automational, informational, or transformational effect as business value. Many of the performance improvements that retailers expect rely on the informational effect of RFID.

Ten RFID applicable business processes are identified to be significant for retail. The most important of those are receiving, tracking and tracing, replenishing, picking, shipping, and checkout followed by storing, returns, demand planning, ordering, and transport. Majority of these are existing business processes that are enhanced by the use of RFID. This means that as of today, RFID is regarded as an implementer that can help to improve business processes. True success will come out when retailers think outside the box and utilize RFID as an enabler of new smart business processes. Factor analysis of the 10 business process items reveals a single factor.

Eleven RFID applicable value chain activities are identified to be significant for retail. The most important of those are in-store operations, replenishment, warehouse management and distribution, and returns / recall followed by sales and different planning activities like promotion planning, merchandise planning, sales planning, assortment planning, and price management. Retailers to this day still focus majorly on the conventional value chain activities that rely on the automational effect of RFID. Factor analysis of the 11 value chain activity items reveals a single factor.

As far as technology choice is considered, UHF reader is the most dominant choice for retailers and case level tagging closely followed by pallet level tagging dominates retail interest. Retailers are interested in item level tagging and could benefit from it significantly but cost issues are hindering progressing to item level tagging. Passive tags are the most popular choice for retailers considering that the read range that they provide is suitable for retail applications.

Factor analysis of the challenge items reveals four factors that are: (a) technical challenges (b) organizational challenges (c) fit challenges (Issues that capture the link between RFID processes and the underlying business processes they are intended to support), and (d) business challenges. The data indicates that the experts still regard technical challenges as the most daunting challenge for RFID implementation in retail followed by organizational challenges, fit challenges, and business challenges.

Top down approach is the diffusion strategy that is appearing to be working for retail with the push to use RFID mainly coming from top management. However, this might change with more technological maturity.

The integrated conceptual framework of the impact of RFID distinguishes between different stages in adoption process and associates key adoption issues with each stage. The framework recognizes that these issues need to be considered using an integrated approach rather than being investigated as separate issues. The holistic approach taken in this study has derived a comprehensive RFID impact framework that has put key issues into a theoretical perspective. It will serve as a platform for future research works in this area. In order to realize values from RFID, retailers must consider these issues together and make better informed business decisions about adopting RFID. The framework has allowed analyzing potential use and benefits of RFID technology across the retail value chain. The conceptual framework should be further refined and revised by putting it through more rigorous empirical investigations. The framework links the research on RFID to existing research in the area of diffusion of innovation and business value of IT.

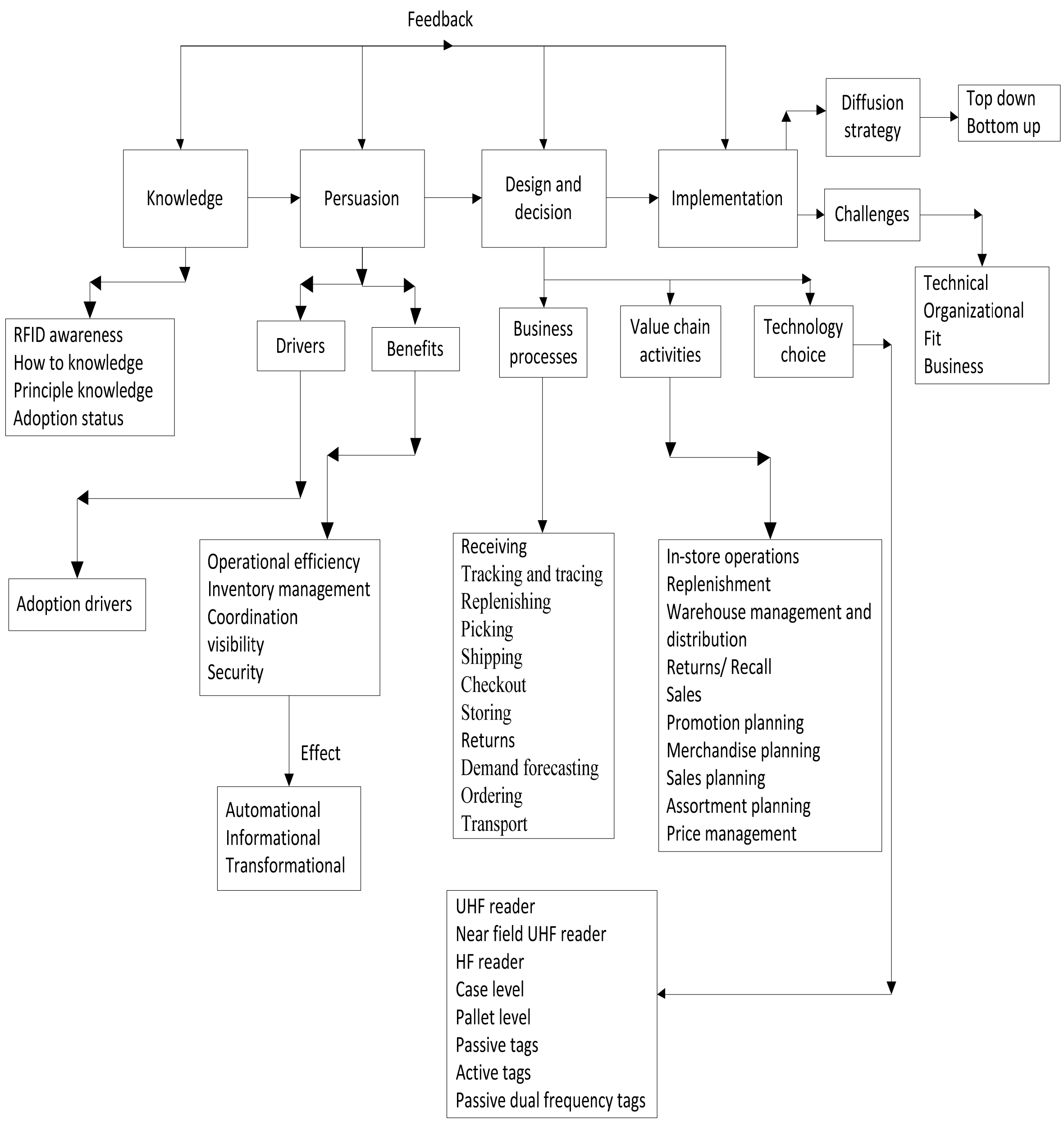


Figure 4-3. Conceptual framework of impact of RFID

4.2.13. Comparison of expert perceptions across business association

After the most significant RFID benefits, applicable business processes and value chain activities, and implementation challenges are identified, differences in expert perceptions based on their field of business association such as consulting, academia, retail, or third party service providers are investigated. This gives some deeper insights on the current RFID adoption status and also act as a pointer to future research initiatives. Also, it could indirectly verify whether the expert sample included in the Delphi study is biased in any ways.

Exploratory statistical analysis of the Delphi data is performed to look for general patterns. Different statistical tests including multivariate analysis of variance (MANOVA) and multiple one way analyses of variance (ANOVA) tests are performed on benefits, business processes, value chain activities, and adoption challenges data across the expert's business associations. The justification for conducting the MANOVA tests is that there are multiple dependent variables each for benefits, business processes, value chain activities, and implementation challenges and it is intended to examine the differences between the levels of the independent variable (Business association) as a function on combination of dependent variables (benefits, business processes, value chain activities, and challenges). The justification for performing multiple ANOVA tests is that this research is exploratory and also because the dependent variables are conceptually independent of each other i.e. they do not measure the same thing (Biskin, 1980). The effect of business association of experts on their perceptions about the significance of the issues is investigated to reach some tentative non-confirmatory conclusions. Since this is an exploratory study a significance level of 10% is used to capture any pattern that is close to being significant. The goal is to draw optimal insights from the data analysis.

4.2.13.1. Multivariate Analysis of Variance (MANOVA) Results

First, a 4 (Business Association) X 22 (Benefits) multivariate analysis of variance (MANOVA) test is conducted to test whether the four groups (Academia, Consulting, Retail, and Third Party Service Providers) are statistically different form each other in terms of their perceptions about RFID benefits.

The null hypothesis is:

H4-1_0*: Perceptions about RFID benefits do not vary as a function of the business association of the experts.*

The analysis reveals a non-significant main effect for business association. The calculated Wilk's Lambda = 0.216, F (66, 100) = 1.01, p-value = 0.480 (> 0.10). Since p-value > 0.10, the null hypothesis $H1_0$ cannot be rejected at 10% significance level and thus it is concluded that the expert perceptions about RFID benefits do not vary as a function of the expert business associations.

Next, a 4 (Business Association) X 11 (Business Processes) multivariate analysis of variance (MANOVA) test is conducted to test whether the four groups (Academia, Consulting, Retail, and Third Party Service Providers) are statistically different from each other in terms of their perceptions about RFID applicability for business processes.

The null hypothesis is:

H4-2$_0$: Perceptions about RFID applicability for business processes do not vary as a function of the business association of the experts.

The analysis reveals a non-significant main effect for business association. The calculated Wilk's Lambda = 0.582, F (33, 172) = 1.05, p-value = 0.404 (> 0.10). Since p-value > 0.10, the null hypothesis H2$_0$ cannot be rejected at 10% significance level and thus it is concluded that the expert perceptions about RFID applicability for business processes do not vary as a function of the expert business associations.

Next, a 4 (Business Association) X 10 (Value Chain Activities) multivariate analysis of variance (MANOVA) test is conducted to test whether the four groups (Academia, Consulting, Retail, and Third Party Service Providers) are statistically different form each other in terms of their perceptions about RFID applicability for value chain activities.

The null hypothesis is:

H4-3$_0$: Perceptions about RFID applicability for value chain activities do not vary as a function of the business association of the experts.

The analysis reveals a significant main effect for business association. The calculated Wilk's Lambda = 0.522, F (30, 171) = 1.411, p-value = 0.090 (< 0.10). Since p-value < 0.10 the null hypothesis H3$_0$ is rejected at 10% significance level and thus is concluded that the expert perceptions about RFID applicability for value chain activities varies as a function of the expert business associations.

Then, a 4 (Business Association) X 12 (Challenges) multivariate analysis of variance (MANOVA) test is conducted to test whether the four groups (Academia, Consulting, Retail, and Third Party Service Providers) are statistically different form each other in terms of their perceptions about RFID benefits.

The null hypothesis is:

H4-4$_0$: Perceptions about RFID adoption challenges do not vary as a function of the business association of the experts.

The analysis revealed a significant main effect for business association. The calculated Wilk's Lambda = 0.484, F (36, 155) = 1.19, p-value = 0.23 (> 0.10). Since p-value > 0.10, the null hypothesis $H4_0$ cannot be rejected at 10% significance level and thus it is concluded that the expert perceptions about adoption challenges do not vary as a function of the expert business associations.

The MANOVA tests show that the overall expert perceptions about RFID adoption benefits, business processes, and challenges are similar which indicates that there is not any inherent bias within each business association group in the sample for Delphi study. However, expert perceptions are different when it comes to value chain activities as expected. Table 4-28 shows the results of the MANOVA tests.

Table 4-28. MANOVA results: Comparison of expert perceptions

Hypotheses	Wilk's Lambda	F-Values	P-Values	Results
$H4\text{-}1_0$: Perceptions about RFID benefits do not vary as a function of the business association of the experts	0.216	1.01	0.480	Cannot reject $H4\text{-}1_0$
$H4\text{-}2_0$: Perceptions about RFID applicability for business processes do not vary as a function of the business association of the experts	0.582	1.05	0.404	Cannot reject $H4\text{-}2_0$
$H4\text{-}3_0$: Perceptions about RFID applicability for value chain activities do not vary as a function of the business association of the experts	0.522	1.41	0.090*	Reject $H4\text{-}3_0$
$H4\text{-}4_0$: Perceptions about RFID implementation challenges do not vary as a function of the business association of the experts	0.484	1.19	0.230	Cannot reject $H4\text{-}4_0$

*Significant at 10% level

4.2.13.2. Univariate Analysis of Variance (ANOVA) results

After performing the multivariate analysis of variance (MANOVA) tests univariate analysis of variance tests are performed on each of the dependent variables separately to identify specific differences in perceptions if they exist.

Table 4-29 shows the significant univariate analysis of variance ANOVA results that are observed. The results of the ANOVA test results are discussed below:

1. Real-time visibility – Benefit 8: The calculated test statistic is $F(3, 69) = 2.913$, p-value = 0.040 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for real-time visibility reveals a significant main effect for business association with consultants [Mean (M) = 4.50, standard error (S.E) = 0.67] reporting more favorable

perception followed by third party service providers (M = 4.28, S.E = 0.75), academics (M = 4.12, S.E = 0.86), and finally retail (M = 3.69, S.E = 1.14).

2. Replenishing – Business process 2: The calculated test statistic is F(3, 69) = 2.442, p-value = 0.071 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for replenishing business process reveals a significant main effect for business association with consultants (M = 4.50, S.E = 0.14) reporting more favorable perception followed by third party service providers (M = 4.33, S.E = 0.20), academics (M = 4.23, S.E = 0.16), and finally retail (M = 3.81, S.E = 0.24).
3. Demand Forecasting - Business process 5: The calculated test statistic is F(3, 69) = 2.332, p-value = 0.082 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for demand forecasting reveals a significant main effect for business association with consultants (M = 4.00, S.E = 0.16) reporting more favorable perception followed by third party service providers (M = 3.89, S.E = 0.24), academics (M = 3.41, S.E = 0.24), and finally retail (M = 3.31, S.E = 0.27).
4. Re-use and recycle / Returns - Business process 6: The calculated test statistic is F(3, 68) = 2.362, p-value = 0.079 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for re-use and recycle / returns reveals a significant main effect for business association with consultants (M = 4.13, S.E = 0.15) reporting more favorable perception followed by third party service providers (M = 3.78,

S.E = 0.22), retail (M = 3.60, S.E = 0.27), and finally academics (M = 3.41, S.E = 0.21).

5. Ordering - Business process 9: The calculated test statistic is F(3, 69) = 2.192, p-value = 0.097 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for ordering reveals a significant main effect for business association with third party service providers (M = 4.11, S.E = 0.21) reporting more favorable perception followed by consultants (M = 3.77, S.E = 0.21), academics (M = 3.41, S.E = 0.24), and finally retail (M = 3.37, S.E = 0.26).
6. Replenishment - Value chain activity 1: The calculated test statistic is F(3, 69) = 2.966, p-value = 0.038 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for replenishment activity reveals a significant main effect for business association with academic experts (M = 4.3529, S.E = 0.12820) reporting more favorable perception followed by consultants (M = 4.3182, S.E = 0.15270), third party service providers (M = 4.5556, S.E = 0.18475), and finally retail (M = 3.8125, S.E = 0.22765).
7. Sales planning - Value chain activity 4: The calculated test statistic is F(3, 68) = 2.713, p-value = 0.052 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for sales planning reveals a significant main effect for business association with consultants (M = 3.95, S.E = 0.15) reporting more favorable perception followed by third

party service providers (M = 3.55, S.E = 0.17), academics (M = 3.41, S.E = 0.21), and finally retail (M = 3.20, S.E = 0.28).

8. Price management - Value chain activity 9: The calculated test statistic is F(3, 69) = 3.767, p-value = 0.014 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for price management reveals a significant main effect for business association with consultants (M = 3.95, S.E = 0.15) reporting more favorable perception followed by third party service providers (M = 3.67, S.E = 0.24), academics (M = 3.35, S.E = 0.27), and finally retail (M = 2.94, S.E = 0.25).
9. Assortment planning- Value chain activity 10: The calculated test statistic is F(3, 69) = 2.231, p-value = 0.092 (< 0.10) and thus the univariate analysis for perceptions about applicability of RFID for assortment planning reveal a significant main effect for business association with consultants (M = 3.86, S.E = 0.18) reporting more favorable perception followed by third party service providers (M = 3.83, S.E = 0.27), retail (M = 3.12, S.E = 0.0.27), and finally academics (M = 3.29, S.E = 0.29).
10. High cost - Challenge 2: The calculated test statistic is F(3, 70) = 5.425, p-value = 0.002 (< 0.10) and thus the univariate analysis for perceptions about high cost reveals a significant main effect for business association with consultants (M = 4.48, S.E = 0.15) reporting more favorable perception followed by retail (M = 4.125, S.E = 0.22), academics (M = 4.120, S.E = 0.21), and finally third party service providers (M = 3.28, S.E = 0.31).

For all the other variables the univariate analysis for expert perceptions reveals a non-significant main effect for business association.

Table 4-29. Significant ANOVA results – Expert perception comparison

Dependent Variables	DF	F-Statistics	P-Values
Real-time visibility- Benefit 8	69	2.913	0.040*
Replenishing - Business process 2	69	2.442	0.071*
Demand forecasting - Business process 5	69	2.332	0.082*
Re-use and recycle / Returns - Business process 6	68	2.362	0.079*
Ordering - Business process 9	69	2.192	0.097*
Replenishment - Value chain activity 1	69	2.966	0.038*
Sales planning - Value chain activity 4	68	2.713	0.052*
Price management - Value chain activity 9	69	3.767	0.014*
Assortment planning - Value chain activity 10	69	2.231	0.092*
High cost - Challenge 2	70	5.425	0.002*

*Significant at 10% level

The results of the multiple ANOVA tests indicate that the perceptions of retail practitioners is more conservative than those from other domains like consulting, third party service providers, and academics. This indicates that most retailers are still focusing on a small spectrum of RFID possibilities and not considering a broader perspective. Or on the other hand this could indicate a possible hype around RFID improving retail operations across value chain. However, we can see from the challenges ANOVA results that the retailers might see an increasing opportunity with RFID, as cost is gradually decreasing with time. For future research the differences in perceptions of experts from various domains is envisioned to be investigated through in-depth interviews.

4.3. Summary

This chapter has derived a conceptual framework that analyses the impact of RFID on retail value chain. The framework puts the findings from the comprehensive content analysis and Delphi study into a theoretical perspective. It distinguishes between different stages in the adoption process and associates key identified adoption issues with a single stage. Key issues that are identified and discussed are benefits, RFID applicable business processes and value chain activities, and challenges. The other issues that are discussed are current RFID adoption status, dimensions of business value of RFID, technology choice, and dominant RFID diffusion strategy in retail. Finally, a comparison of expert perceptions about the key issues across business association is discussed.

Chapter 5

Data Analysis and Discussion: A Conceptual Framework of RFID Adoption

This chapter derives the conceptual framework of RFID adoption in retail discussing the framework development, construct measures, reliability and validity of the measurements, multivariate discriminant analysis (MDA) test results, and discussion. The framework could be generalized for other auto-id technologies as well.

5.1. Overview

Despite extensive research on adoption and diffusion of innovation, adoption of emerging technologies with specific characteristics is still not well understood (Rogers, 1995). Adoption of electronic data interchange (EDI) is an example where generalizations of diffusion theory could not be directly applied and new models were developed to understand the adoption patterns by identifying adoption drivers (Chwelos et al., 2001; Sharma et al., 2008).There are many studies on technology adoption in the field of information systems (IS). The unique characteristics offered by RFID distinguish it from other technologies such as internet and EDI and warrants further investigation around RFID adoption specifically. Many of the studies of organizational adoption of technology have drawn from the work of Tornatzky and Fleishcher's TOE (technology-organization-environment) framework (Tornatzky and Fleischer, 1990; Chwelos et al., 2001; Teo et al., 2004) who grouped factors influencing organizational adoption into technological, organizational, and environmental contexts. Technological context refers to innovation characteristics. The organizational context describes the organization and its characteristics, and the environmental context refers to the surrounding in which an organization conducts its business. It encompasses the industry and dealings with business partners, competitors, and government. Prior RFID adoption studies have not always investigated the three contexts in a comprehensive manner. Most of these have focused on a few factors instead (Brown and Russell, 2007). Additionally, most of the previous studies show the importance of technological factors; however the effects of organizational and environmental factors have been varied across different industrial contexts (Wang et al., 2010). Thus there is still more need to analyze the drivers of RFID adoption in different industrial contexts for a better understanding.

This study explores factors that drive RFID adoption, inspired by the TOE framework that draws from multiple theoretical bases. In addition to the basic constructs of the TOE framework, value chain factors are also studied since RFID technology is primarily used to streamline value chain. Thus technological, organizational, environmental, and value chain adoption factors are investigated to develop the conceptual framework of RFID adoption in retail.

5.2. Research framework and hypotheses

A wide range of factors has been found in the literature that facilitates or inhibits technology adoption. In this study a few factors that are believed to be important in understanding RFID adoption are investigated. The proposed research framework on RFID adoption identifies and evaluates the antecedents of RFID adoption intention.

The dependent variable is retailer's RFID adoption intent. Intention to behavior is a suitable predictor of behavior since behavior is usually more difficult to measure reliably (Ajzen, 1991). Given the newness of RFID technology, intention which refers to a future behavior is more meaningful than behavior. The three contexts of technology, organization, and environment form the basis for developing the adoption framework and factors relevant to the adoption of RFID within each category are highlighted. A fourth category of value chain context is introduced in the model considering the unique characteristics of RFID and its applicability in a value chain. The contextual factors are synthesized from innovation adoption research that includes work on different kinds of innovation in organizational context, general research on information systems implementation, and research on strategic information systems like inter-organizational systems (IOS) and are put into a testable model for RFID adoption. Please note that experts who support RFID adoption in retail represent actual retail adopters whereas experts who do not support such adoption represent non-adopters in this study. It is assumed that the behavior of actual adopters and non-adopters of RFID is similar to that of the experts. Thus this study will be discussed in terms of adopters and non-adopters from this point onwards.

The differences in profiles of adopters and non-adopters with respect to the four categories of contextual factors provide insight into the variables that are important to adoption. The adoption framework consists of twelve determinants or antecedents that are hypothesized to influence RFID adoption in retail. This study focuses on identifying factors that can predict RFID adoption and thus the relationships among the twelve factors are beyond the scope of this research. The proposed research framework is shown in Figure 5-1.

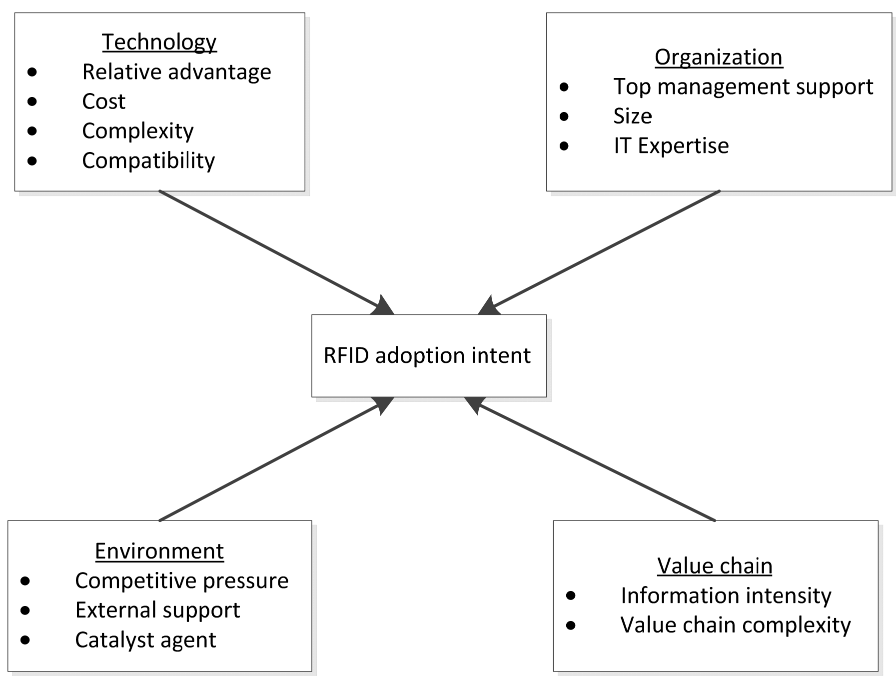


Figure 5-1. Conceptual framework of RFID adoption

5.2.1. Technological context

Technological factors represent characteristics of an innovation as defined by (Tornatzky and Fleischer, 1990). Several innovation characteristics have been studied as the basis for innovation diffusion research. These characteristics that are found to be used most frequently are relative advantage, complexity, communicability, divisibility, cost, profitability, compatibility, social approval, trialability, and observability (Tornatzky and Klein, 1982). Of these characteristics relative advantage, compatibility, and complexity consistently predicted adoption (Grover, 1993). Cost is also found to be significant in studies of innovation adoption and IT diffusion (Premkumar et al., 1994). Thus these three characteristics along with cost are included in the research framework. Specifically, these four characteristics have been suggested as being important for RFID adoption (Ranganathan and Jha, 2005; Sharma and Citurs, 2005; Brown and Russell, 2007).

52.1.1. Relative advantage

Relative advantage is defined as the degree to which an innovation is perceived to be better than the idea it supersedes providing greater direct or indirect organizational benefits. Relative advantage has consistently been identified as a predictor of adoption intent in innovation diffusion literature (Premkumar and Roberts, 1999). It has also been considered as the most frequently cited facilitator of RFID adoption (Sharma and Citurs, 2005). Perceived RFID benefits include greater supply chain visibility, increased speed and efficiency of operations, reduced labor costs and improved security, and improved customer service (Kinsalla, 2003; Wu et al., 2006). RFID is expected to provide greater competitive advantages to companies (Ngai et al., 2008; Chao et al., 2007). Thus companies which perceive higher relative advantages in RFID technology are more likely to adopt it. The proposed hypothesis is thus:

H5-1: Technological factor relative advantage positively influences RFID adoption intent.

5.2.1.2. Cost

Perceived costs of innovations lead to lower intent to adopt despite the benefits that they provide. Thus benefits must exceed the cost of innovation adoption for decisions to adopt it. Thus cost relative to benefits is an important consideration for most innovation adoption decisions and it is true for RFID adoption as well. According to (Tornatzky and Klein, 1982) technologies that are low in cost are more likely to be adopted. (Premkumar et al., 1994) found cost to be an important variable in EDI adoption. RFID technology is a costly investment for companies involving costs of tags, hardware and software, data management and integration, and reengineering business processes that could inhibit its adoption. Cost has been proposed to be used as a predictor of RFID adoption in several studies (Sharma and Citurs, 2005; Brown and Russell, 2007). Thus companies which perceive higher cost relative to benefits in RFID technologies are less likely to adopt it. The proposed hypothesis is thus:

H5-2: Technological factor higher cost negatively influences RFID adoption intent.

5.2.1.3. Complexity

Complexity is defined as the degree to which an innovation is perceived as relatively difficult to understand and use. New technical skills are required to correctly use the innovation that tends to inhibit its adoption (Cooper and Zmud, 1990). Since complexity can be a deterrent to successful implementation followed by use of an innovation, it is usually negatively associated with adoption (Premkumar et al., 1994; Premkumar and Roberts, 1999). Although RFID provides several organizational benefits, the perceived characteristics of the technology is still complex. Managing and integrating large volumes of data generated by RFID system is difficult thus making the potential benefits of the technology unclear. This is one of the major inhibitors of RFID adoption and has been proposed in several RFID adoption studies (Sharma and Citurs, 2005; Brown and Russell, 2007). The diversity of RFID technology available in terms of multiple standards, operating frequencies, tag types and so on makes RFID implementation a very complicated task (Wang et al., 2010). Thus companies which perceive greater complexity in RFID technologies are less likely to adopt it. The proposed hypothesis is thus:

H5-3: Technological factor complexity negatively influences RFID adoption intent.

5.2.1.4. Compatibility

Compatibility refers to the degree to which an innovation is consistent with existing values, needs, and practices of the adopting organization (Rogers, 1995). It is an important determinant of innovation adoption because the new innovation can bring significant changes in existing work procedures. It has been widely used as a predictor of adoption in innovation diffusion research (Premkumar and Roberts, 1999). RFID systems bring significant changes in business processes in order to fully utilize its potentials. Companies need to integrate RFID systems with other applications and need to cooperate with value chain partners and thus they will not intend to adopt it if they do not believe that the technology is compatible with their existing practices and infrastructure. Compatibility has been suggested to be used as a predictor of RFID adoption in several studies (Sharma and Citurs, 2005; Brown and Russell, 2007; Wang et al., 2010). Thus companies which perceive greater compatibility in RFID technologies are more likely to adopt it. The proposed hypothesis is thus:

H5-4: Technological factor compatibility positively influences RFID adoption intent.

5.2.2. Organizational context

Organizational factors represent organizational characteristics that influence innovation adoption decisions. Organizational factors identified in innovation adoption studies are top management support, organizational size, existence of product champions, and availability of resources (Premkumar and Ramamurthy, 1995). The organizational context being extremely relevant to innovation adoption process was shown by (Orlikowski, 1993). These characteristics are suggested to be important for RFID adoption as well (Sharma and Citurs, 2005; Brown and Russell, 2007; Wang et al., 2010).

The organizational characteristics of top management support, size, and IT expertise are included in the research model.

5.2.2.1. Top management support

Top management support is crucial for innovation adoption decisions. The decisions made by the top management are likely to impact organizational growth and development because higher management level has greater influence upon strategic decisions (Carpenter et al., 2004). Top management support is defined as the degree to which the values of the management are in favor of the new innovation adoption thus creating a supportive climate and providing adequate resources for its adoption (Useem, 1993; Kwon and Zmud, 1987; Teo et al., 2004). Top management support is very critical for RFID adoption since RFID implementation requires adequate resources, process reengineering, and overcoming employee resistance to change (Hoske, 2004; Wang et al., 2010). Thus companies which receive greater top management commitment towards RFID technologies are more likely to adopt it. The proposed hypothesis is thus:

H5-5: Organizational factor top management support positively influences RFID adoption intent.

5.2.2.2. Size

Organizational size has been shown to impact innovation adoption by several studies (Premkumar and Roberts, 1999; Delone, 1981; Rogers, 1995). Large organizations typically have slack resources to experiment with a new innovation and then make an informed adoption decision (Premkumar and Roberts, 1999). Size has been suggested as an important predictor of RFID adoption in several studies (Brown and Russell, 2007; Wang et al., 2010). Thus companies which are larger in size are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-6: Organizational factor organizational size positively influences RFID adoption intent.

5.2.2.3. IT Expertise

Technological resources represented by appropriate technology infrastructure and skilled people are critical for innovation adoption. Companies that do not have adequate IT expertise may be unaware of new technologies or may not be in a position to deploy them. IT expertise has been used as an important variable predicting adoption in innovation diffusion research (Premkumar and Roberts, 1999; Kwon and Zmud, 1987). It has been suggested to be used in RFID adoption studies as well since the presence of adequate IT expertise may reduce costs and efforts to integrate RFID technologies with existing systems (Sharma and Citurs, 2005; Brown and Russell, 2007). Thus companies which have greater IT expertise are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-7: Organizational factor IT expertise positively influences RFID adoption intent.

5.2.3. Environmental context

Factors external to a firm but influencing a firm's functioning influences organizational adoption of new innovations. Tornatzky and Fleischer (1990) identified competitive pressure, governmental regulations, and consumer readiness as environmental factors influencing innovation adoption. Competitive pressure, external support, and existence of catalyst agents such as government influence and development of standards are some of the factors within the environment context that have been used in general innovation diffusion research and specific RFID adoption studies (Premkumar and Roberts, 1999; Ranganathan and Jha, 2005; Sharma and Citurs, 2005, Orlikowski, 1993; Brown and Russell, 2007). These three environmental factors are included in the research framework.

5.2.3.1. Competitive pressure

Competitive pressure refers to the degree to which an innovation is adopted in the firm's industry. It is perceived to be positively influencing innovation adoption in an organization (Premkumar and Roberts, 1999; Kuan and Chau, 2001). RFID technologies provide several organizational benefits that lead to competitive advantage and is thus of immense interest to several firms particularly retailers. A firm without RFID technology may experience more pressure when more competitors have adopted it. Competitive pressure is suggested to be used as a predictor of RFID adoption in several studies (Brown and Russell, 2007; Sharma et al., 2008; Wang et al., 2010). Thus companies which experience greater competitive pressure are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-8: Environmental factor competitive pressure positively influences RFID adoption intent.

5.2.3.2. External support

External support represents the availability of support for implementing and maintaining an innovation from outside of the firm. Vendor and third party service provider support and support from powerful business partners positively influences innovation adoption as organizations are more willing to invest even if they do not have internal expertise to handle it. External support has been used as a determinant of adoption in innovation diffusion research (Delone, 1981; Kwon and Zmud, 1987). It is suggested to be used as a predictor of RFID adoption in several studies (Brown and Russell, 2007; Wang et al., 2010). Thus, companies which experience greater external support are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-9: Environmental factor external support positively influences RFID adoption intent.

5.2.3.3. Catalyst agent

Catalyst agents external to organizations include vendors trying to sell a new innovation, government and industry bodies promoting its adoption, and increased general awareness and thus acceptance and readiness with innovation maturity (Teo et al., 2004; Brown and Russell, 2007). Existence of such catalyst agents could positively influence RFID adoption decisions and has been suggested in literature (Brown and Russell, 2007; Sharma et al., 2008). Thus companies which experience greater external catalyst agents are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-10: Environmental factor catalyst agent positively influences RFID adoption intent.

5.2.4. Value chain context

Value chain context is critical for RFID adoption because the primary use of RFID is to streamline the value chain through improved visibility that could lead to savings for the adopting organization. Information intensity in the value chain and value chain complexity are the two variables in this group that are included in the research model.

5.2.4.1. Information intensity

Information intensity refers to the degree to which information is present in a product or service thus requiring more information to order or use those (Wang et al., 2010). The more information intensive is a value chain, the more suitable it is for enhancement with new innovation (Grover, 1993; Porter and Miller, 1985; Ranganathan and Jha, 2005). It has been suggested to be a determinant factor in RFID adoption (Ranganathan and Jha, 2005; Wang et al., 2010). Thus companies which sell information intensive products or services are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-11: Value chain factor information intensity positively influences RFID adoption intent.

5.2.4.2. Value chain complexity

Value chain complexity refers to the degree of complexity in the value chain of the adopting organization in terms of dealing with too many value chain partners and tremendous uncertainty. It is an extension of the concept of system complexity inhibiting adoption of new technologies (Grover and Gosler, 1993). It has been suggested to be a significant predictor of RFID adoption (Ranganathan and Jha, 2005). Thus companies which conduct businesses in complex value chain environments are more likely to adopt RFID technology. The proposed hypothesis is thus:

H5-12: Value chain factor value chain complexity positively influences RFID adoption intent.

5.3. Methodology

This section discusses the research methodology employed for developing the conceptual framework of RFID adoption. Data is collected through Delphi technique to accomplish research goals. The purpose of this study is to investigate antecedents of RFID adoption in retail. A statistical method of multivariate discriminant analysis (MDA) is used to identify the significant antecedents and their relative importance. Construct measures, and validity and reliability of the study instrument is discussed next.

5.3.1. Construct measures

All constructs in this study employs multiple item scales. The majority of the items are written in the form of statements with which the respondent is to disagree or agree on a 5-point Likert scale. The principal construct measures are based on existing instruments. Items are modified to fit the context of RFID when necessary. New items were constructed from statements in relevant literature after a thorough and extensive review.

The adoption of RFID technology is measured according to the perceived intent to adopt RFID technology by retailers. Intent to adopt a new technology is positively associated with the actual adoption behavior (Ajzen, 1985; Davis 1989). This study assumes that retailers will be more likely to adopt RFID technology if they are perceived to have strong intent. The dependent variable of retailer's RFID adoption intent is recoded as a dichotomous variable measuring whether the experts disagree or agree with retailers RFID adoption intent. The construct was originally operationalized via a five-point Likert scale which was later recoded as disagree and agree.

Relative advantage is measured using six items that are constructed from content analysis results. The wording of the statements of the items is adapted from (Premkumar and Roberts, 1999). The items assessed the perceived benefits of RFID for retailers. Cost is measured by three items adapted from (Premkumar and Roberts, 1999) that determined the cost of RFID technology relative to its benefits. Complexity is measured by four items adapted from (Premkumar and Roberts, 1999) that determines how difficult it is to develop and use RFID technology for retailers. Compatibility is assessed by two items adapted from (Premkumar and Roberts, 1999; Grover, 1993) that determined if RFID technology is compatible with retail business approaches, values, and existing infrastructure.

Top management support is measured by four items adapted from (Premkumar and Roberts, 1999) that determines the level of top management commitment to RFID technology. A single item is created to assess whether the size of retail organization influences RFID adoption. IT Expertise is assessed by three items created from statements from (Brown and Russell, 2007) that determine the existing IT capability required to handle RFID systems. Competitive pressure is assessed by two items adapted from (Premkumar and Roberts, 1999). External support is assessed by four items adapted from (Premkumar and Roberts, 1999). Existence of catalyst agent is assessed by four items created from statements in (Brown and Russell, 2007; Sharma and Citurs, 2008)

Information intensity is measured by four items adapted from (Grover, 1993) and value chain complexity is measured by two items created from statements in

(Ranganathan and Jha, 2005). Table 5-1 summarizes the measurement items of the independent variables.

Table 5-1. Measurement items of adoption independent variables

Variables	Measurement Items
Relative advantage	RA1. RFID allows for improved inventory management RA2. RFID provides better information accuracy for better decision making and collaboration RA3. RFID provides improved visibility RA4. RFID allows for improved customer service levels and sales RA5. RFID provides improved operational efficiency RA6. RFID provides improved security against theft and counterfeiting
Cost	C1. The costs of adopting RFID technology are far greater than the benefits C2. The cost of maintenance and support of RFID technology is very high C3. The amount of money and time invested in training employees to use RFID technology is very high
Complexity	CX1. The skills required to use RFID technology are too complex for employees CX2. Integrating RFID technology in current retail work practices is very difficult CX3. Integrating RFID systems with existing IT systems is very complex CX4. Massive amounts of data generated by RFID is very difficult to manage
Compatibility	CM1. Implementing the changes caused by RFID adoption is not compatible with most retailer business approaches and objectives CM2. RFID is not compatible with retailers' experience with similar technology
Top management support	TS1. Top management in retail enthusiastically supports the adoption of RFID technology TS2. Top management in retail allocates adequate resources for adoption of RFID technology TS3. Top management in retail is aware of the benefits from RFID TS4. Top management in retail actively encourages employees to use RFID technology in their daily tasks
Size	S1. Organization size positively influences RFID adoption in retail
IT expertise	IE1. Greater IT expertise in an organization positively influences RFID adoption in retail IE2. Greater strategic IT planning positively influences RFID adoption in retail IE3. Most big retailers have a sophisticated database and telecommunication facility
Competitive pressure	CP1. Retailers will lose customers to competitors if they do not adopt RFID technology CP2. It is a strategic necessity to use RFID to compete in marketplace
External support	ES1. There are third party service providers that provide technical support for effective use of RFID technology ES2. There are agencies who provide training on RFID technology ES3. Technology vendors actively market RFID technology by providing incentives for adoption ES4. Technology vendors promote RFID technology by offering free training sessions
Catalyst agent	CA1. Vendors are trying very hard to sell RFID technology to retailers CA2. Government is promoting RFID adoption by retailers through specific mandates CA3. EPC global initiative for standardization is promoting RFID adoption in retail CA4. Perceived consumer readiness for RFID technology is positively influencing RFID adoption in retail
Information intensity	II1. The product/service in retail generally requires a lot of information to sell II2. The product/service in retail is complicated or complex to understand II3. The ordering of product/service in retail is generally a complex process II4. The products in retail industry are characterized by a long cycle time from order to delivered product
Value chain complexity	VC1. Typically retailers deal with too many value chain partners for doing business VC2. Typically retailers deal with a lot of uncertainty while doing business with value chain partners

5.3.2. Instrument validation

Cronbach's alpha is applied to test reliability of the constructs. The results in table 5-2 indicate that all the constructs have adequate alpha values (> 0.6) which is acceptable for exploratory research (Premkumar and Roberts, 1999), except catalyst agent. It could be explained by the use of few items for measuring catalyst agent. Some more relevant items need to be added in future.

Table 5-2. Reliability of measurement items

Variables	No. of Items	Alpha-Value
Relative advantage	6	0.834
Cost	3	0.780
Complexity	4	0.864
Compatibility	2	0.830
Top management support	4	0.825
Size	1	N/A
IT expertise	3	0.665
Competitive pressure	2	0.789
External support	4	0.755
Catalyst agent	4	0.320
Information intensity	4	0.820
Value chain complexity	2	0.816

Content validity is established through an extensive process of literature search and refinement followed by strict scrutiny for appropriate mapping of the constructs by a team of researchers.

Factor analysis is used to evaluate construct validity. Factor analysis addresses the issues of interrelationships among a large number of variables, and explains these variables in terms of their common underlying dimension (Zhang et al., 2000). The main purpose is to summarize the information into a smaller set of new dimensions without losing majority of the information (Hair et al., 1983). Although the questionnaire developed for this study has been adapted from previous studies, new items are included. Thus, construct validity is examined using principal component analysis (PCA) with varimax rotation rather than confirmatory. Principal component analysis assists in identifying whether the selected items cluster on one or more than one factor which is important if there are three or more items measuring a single construct (Zhang et al., 2000). According to (Hair et al., 1983) factor loadings greater than 0.3 are considered as significant; factor loadings greater than 0.4 are considered to be moderately significant; and factor loadings greater than 0.5 are considered to be very significant. The standard criteria of Eigen-value greater than 1.0, factor loadings greater than 0.3, and a well explained factor structure is used in the analysis (Zeller, 1980). The items loaded on twelve factors that directly mapped with the theorized constructs. Cross loadings of items on other factors is minimal, except in four instances.

In the first instance, the items measuring compatibility and cost loaded with the four items measuring complexity. However, an independent factor analysis of the items measuring just the three constructs reveals that they loaded on two separate variables. The two items measuring compatibility loaded with the four items measuring complexity. A following independent factor analysis of the items measuring just the two constructs of complexity and compatibility again loaded together in a single factor. However, complexity and compatibility have been verified to be separate constructs in past research and thus it was decided to consider them as two separate variables.

In the second instance, one item measuring cost loaded with two items measuring existing IT expertise. An independent factor analysis of the items measuring just the two constructs of cost and IT expertise reveals that they loaded on two separate factors mapping to the two constructs. Based on the results of the independent factor analysis and findings from past research it was decided to consider cost and IT expertise as two separate variables.

In the third instance two items measuring catalyst agent loaded with the two items measuring value chain complexity. An independent factor analysis of the items measuring just the two constructs of catalyst agent and value chain complexity reveals that they loaded on two separate factors mapping to the two constructs. Based on the results of the independent factor analysis and findings from past research it is decided to consider catalyst agent and value chain complexity as two separate variables.

In the fourth instance, one item measuring relative advantage loaded with one item measuring catalyst agent. An independent factor analysis of the items measuring just the two constructs of catalyst agent and relative advantage reveals that they loaded on two separate factors mapping to the two constructs. Based on the results of the independent factor analysis and findings from past research it was decided to consider catalyst agent and relative advantage as two separate variables.

Thus, after clarifying the spurious factors that emerged from the factor analysis using independent factor analysis of certain constructs, twelve meaningful constructs remained in the research framework. Items measuring the catalyst agent construct are created from statements in literature and have not been validated in prior research. From the reliability and validity tests of the instrument it is obvious that the items measuring the construct of catalyst agent need to be further refined for future research. It is believed that other items need to be added to measure the construct completely. Table 5-3 shows the results of factor analysis of the twelve independent variables. Please note that item codes used in table 5-3 has been defined in table 5-1.

Table 5-3. Factor loadings for constructs

Constructs	Items	Loadings	Eigen-Value	% Variance Explained
Factor 1 Complexity Compatibility Cost	CX2	0.852	6.782	17.85
	CX3	0.828		
	CX1	0.758		
	CM2	0.741		
	CM1	0.727		
	CX4	0.726		
	C3	0.575		
	C2	0.481		
Factor 2 Relative advantage	RA1	0.878	6.613	16.22
	RA3	0.857		
	RA2	0.825		
	RA4	0.609		
	RA5	0.577		
Factor 3 Top management support	TS2	0.880	2.848	7.49
	TS1	0.848		
	TS3	0.774		
	TS4	0.586		
Factor 4 Information intensity	II2	0.816	2.588	6.81
	II4	0.801		
	II3	0.797		
	II1	0.433		
Factor 5 External support	ES3	0.832	2.136	5.62
	ES4	0.662		
	ES2	0.657		
	ES1	0.626		
Factor 6 IT Expertise	IE2	0.844	1.894	4.98
	IE1	0.839		
Factor 7 Competitive pressure	CP2	0.862	1.772	4.68
	CP1	0.813		
Factor 8 IT Expertise Cost	IE3	0.847	1.718	4.52
	C1	0.638		
Factor 9 Relative advantage Catalyst agent	RA6	0.769	1.383	3.64
	CA4	0.628		
Factor 10 Value chain complexity Catalyst agent	VC1	0.712	1.104	2.90
	VC2	0.623		
	CA2	0.361		
	CA3	0.472		
Factor 11 Size	S1	0.758	1.078	2.84
Factor 12 Catalyst agent	CA1	0.74	1.012	2.68

5.4. Results

Multivariate discriminant analysis (MDA) is used to identify each predictor's contribution to a linear function that best discriminates between two or multiple groups. It provides a statistical method to classify the RFID adopter and non-adopter and also allows determining which of the independent variables would contribute to RFID adoption. The objective is to maximize between-group variances compared to within-group variances based on a series of discriminant scores generated by a linear combination of independent variables, so that the discriminant function separates the groups well.

The composite scores of the twelve factors are first calculated by averaging the original items scores. Table 5-4 shows the twelve factors of the RFID adoption model represented by the rating average (mean) of the expert's responses, standard deviation, and the 90% lower bounds of the confidence intervals (One sample t test results).

Table 5-4. Means and standard deviations of the independent variables

Independent Variables	Rating Average (Mean)	Std. Deviation	($H_{\mu i}$: $\mu_i > 3$) 90% Lower Bound
Relative advantage	4.16	0.551	4.077
Cost	2.73	0.948	2.587
Complexity	2.50	0.798	2.380
Compatibility	2.42	0.890	2.286
Top management support	2.75	0.735	2.639
Size	3.38	1.150	3.207
IT expertise	3.75	0.687	3.647
Competitive pressure	2.76	1.005	2.609
External support	3.43	0.665	3.330
Catalyst agent	3.13	0.567	3.045
Information intensity	2.75	0.783	2.632
Value chain complexity	3.02	0.950	2.877

The twelve factors are then taken as independent variables and the perceived retailer's intent to adopt RFID as the dependent variable; and consequently employed the method of multivariate discriminant analysis (MDA) is employed to determine their relationship. To test the model all twelve independent variables are entered in one step to generate the discriminant function. However, discriminant analysis assumes homogeneity of co-variances which is examined with Box's test of equality of co-variances. The null hypothesis for Box's test is that the variances of the independent variables among categories of the categorical dependent variable are not homogeneous. The value of Box's M, F-value, and the level of significance of the test are 116.536, 1.000, and 0.480 respectively. Since the significance level 0.480 is greater than cut off value of 0.10 (Cannot reject the null hypothesis of equal population co-variance matrices at 0.10 significance level), homogeneity of co-variance is accepted and thus discriminant analysis can be performed.

Discriminant analysis is also sensitive to multicollinearity. A check on multicollinearity is looking at the pooled within-groups correlation matrix. When assessing the correlation matrix for multicollinearity a rule of thumb is that no r (correlation value) > 0.90 and not several r > 0.80. Table 5-5 below provides the pooled correlation matrices. Looking at table 5-5, all correlation values are < 0.658 and thus there is no support for the existence of multicollinearity in these independent variables. So discriminant analysis can be performed.

Table 5-5. Pooled within-groups matrices to test multicollinearity.

		RA	C	CX	CM	TS	S	IE	CP	ES	CA	II	VC
Corr.	Relative advantage	1.000	-.398	-.231	-.172	-.097	.120	.243	.005	.338	.187	.125	.217
	Cost	-.398	1.000	.540	.514	.303	-.128	209	.272	-.330	.046	.110	-.047
	Complexity	-.231	.540	.000	.657	.290	.151	.240	-.049	.240	.293	.361	.055
	Compatibility	-.172	.514	.657	1.000	.273	-.023	.122	-.296	-.084	.385	.206	.110
	Top management support	-.097	.303	.290	.273	1.000	.151	.043	-.176	-.178	.218	.082	.006
	Size	120	-.128	.151	-.023	.151	1.000	.268	.164	-.090	.081	.273	.280
	IT Expertise	.243	.209	.240	.122	.043	.268	1.000	.002	.127	.121	.318	.255
	Competitive pressure	.005	-.272	-.049	-.296	-.176	.164	.002	1.000	.176	.224	.219	.293
	External support	.338	-.330	-.240	-.084	-.178	-.090	.127	.176	1.000	.181	.039	.093
	Catalyst agent	1.87	.046	.293	.385	.218	.081	.121	.224	.181	1.000	.352	.308
	Information intensity	.125	.110	.361	.206	.082	.273	.318	.219	.039	.352	1.000	.517
	Value chain complexity	.217	.047	055	.110	.006	.280	.255	.293	.093	.308	.517	1.000

Discriminant model is generated for perceived RFID adoption intent of retailers. The value of Wilk's Lambda, chi-square value, and the level of significance is shown in table 5-6. The model is significant with p-value = 0.003 at 0.10 significance level. The standardized discriminant coefficients and discriminant loadings for the variables are also provided in table 5-6. Univariate statistics in terms of group-wise means and F-value significance on equality of means are provided for comparative analysis. Discriminant loadings (Structural correlation), measuring the simple linear correlation between each predictor variables and the extracted discriminant function, is used to determine the significance of the variables. The general guideline is that the values above 0.3 are satisfactory and acceptable (Hair et al., 1983).

Table 5-6. Discriminant analysis – RFID adoption

Wilk's Lambda = 0.559, Chi-Square = 29.62, DF = 12, Sig = 0.003					
Variables	**Discriminant Coefficients**	**Discriminant Loadings**	**Univariate Analysis Group Mean (S.D)**		
			Adopter	**Non-adopter**	**Sig**
Relative advantage	0.705	0.600	4.34 (0.45)	3.50 (0.62)	0.000
Competitive pressure	0.691	0.526	3.02 (0.95)	2.06 (0.87)	0.001
Catalyst agent	0.183	0.482	3.25 (0.53)	2.75 (0.55)	0.002
Value chain complexity	0.057	0.344	3.17 (0.96)	2.53 (0.92)	0.025
IT expertise	0.220	0.289	3.89 (0.60)	3.54 (0.66)	0.058
Top management support	0.387	0.252	2.87 (0.76)	2.51 (0.55)	0.097
Information intensity	-0.116	0.212	2.78 (0.78)	2.47 (0.71)	0.162
Cost	0.068	-0.116	2.56 (0.85)	2.77 (1.02)	0.441
External support	-0.280	0.091	3.49 (0,70)	3.37 (0.57)	0.545
Compatibility	0.041	-0.069	2.29 (0.88)	2.40 (0.78)	0.646
Size	-0.340	-0.018	3.39 (1.16)	3.44 (1.21)	0.903
Complexity	-0.054	0.009	2.44 (0.85)	2.42 (0.65)	0.952

The significant variables thus are relative advantage, competitive pressure, catalyst agent, and value chain complexity that discriminate between adopter and non-adopters. The univariate significance levels corresponding to the F statistics given in table 5-6 also indicate that these variables are significant independently as well.

Table 5-7 shows the results of one sample t tests performed on the adopter and non-adopter univariate group means. The one sample t tests are performed to verify agreement (The alternative hypotheses are H_{ai}: $\mu_i > 3$). The means are compared with 3 because in a scale of 1-5, 3 indicate agreement.

Table 5-7. One sample t test results of univariate group means

Variables	Adopter Mean (S.D)	Non-Adopter Mean (S.D)	H_a: μi > 3	
			Adopter 90% Lower Bound	Non-Adopter 90% Lower Bound
Relative advantage	4.34 (0.45)	3.50 (0.62)	4.25	3.38
Competitive pressure	3.02 (0.95)	2.06 (0.87)	2.84	1.89
Catalyst agent	3.25 (0.53)	2.75 (0.55)	3.15	2.64
Value chain complexity	3.17 (0.96)	2.53 (0.92)	2.98	2.35
IT expertise	3.89 (0.60)	3.54 (0.66)	3.77	3.41
Top management support	2.87 (0.76)	2.51 (0.55)	2.72	2.40
Information intensity	2.78 (0.78)	2.47 (0.71)	2.63	2.33
Cost	2.56 (0.85)	2.77 (1.02)	2.39	2.57
External support	3.49 (0,70)	3.37 (0.57)	3.35	3.26
Compatibility	2.29 (0.88)	2.40 (0.78)	2.12	2.25
Size	3.39 (1.16)	3.44 (1.21)	3.16	3.20
Complexity	2.44 (0.85)	2.42 (0.65)	2.27	2.29

Classificatory test is done to determine the ability of the model to classify accurately. The classification result is used to assess how well the discriminant function works, and if it works equally well for each group of the dependent variable. Classification result is provided in table 5-8. From table 5-8 it is observed that the classificatory ability of the discriminant model is 84.7% for original grouped cases and 78% for cross-validated grouped cases.

Table 5-8. Classification result of RFID adoption model

		Retailers RFID Adoption Intent	Predicted Group Membership		Total
			Disagree	Agree	
Original	Count	Disagree	9	7	16
		Agree	2	41	43
	%	Disagree	56.3	43.8	100.0
		Agree	4.7	95.3	100.0
Cross-validated[a]	Count	Disagree	8	8	16
		Agree	5	38	43
	%	Disagree	50.0	50.0	100.0
		Agree	11.6	88.4	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 84.7% of original grouped cases correctly classified.

c. 78.0% of cross-validated grouped cases correctly classified.

Looking at the discriminant coefficients given in table 5-6 it is observed that the four significant variables relative advantage, competitive pressure, catalyst agent, and value chain complexity positively influences RFID adoption. Remaining antecedents IT expertise, top management support, information intensity, cost, external support, compatibility, size, and complexity are found not be significant. IT expertise, top management support, information intensity are expected to be significant antecedents. Thus, the results were in contradiction to what was expected and the argument for the insignificance could be that the variables came out to be insignificant in the presence of other stronger antecedents. However, the discriminant loadings for the factors of IT expertise, top management support, and information intensity are close to the cut off value of 0.3 as observed from table 5-6. The univariate significance levels corresponding to the F statistics for IT expertise and top management support given in table 5-6 indicate that these variables are significant independently.

Since these three variables came out to be close to being significant, a follow up multivariate discriminant analysis (MDA) is performed with step-wise variable selection with the selection criteria of minimizing Wilk's Lambda. When all variables are entered together for discriminant analysis, subtle influences of weaker variables get overshadowed by variables whose influence is stronger. From the results, it is observed that top management support is a significant predictor of retailer's RFID adoption intent along with the four other variables relative advantage, competitive pressure, catalyst agent, and value chain complexity. However, IT expertise and information intensity are still insignificant. Also the variables value chain complexity and catalyst agent along with the insignificant variables are not included in the overall discriminant model when independent variables are entered step-wise. And the overall discriminant model with step-wise variable entry is not as accurate as the previous model where all variables are entered together. Thus, it is decided to select the discriminant model where all variables are entered together as the final selected model and it implies that top management support is not a significant predictor of retailer's RFID adoption intent. The effect of the top management support variable might have been over-shadowed due to the presence of other stronger variables. The variable IT expertise is very close to the cut off value of 0.3. Results of the multivariate discriminant analysis with step-wise variable selection are provided in Appendix B. Table 5-9 presents the results of the discriminant model (all variables entered together) in a summarized form.

Table 5-9. Summary results of discriminant analysis

Variables	Hypotheses	Results
Relative advantage	H5-1: Technological factor relative advantage positively influences RFID adoption intent	**Accepted**
Cost	H5-2: Technological factor higher cost negatively influences RFID adoption intent	Rejected
Complexity	H5-3: Technological factor complexity negatively influences RFID adoption intent	Rejected
Compatibility	H5-4: Technological factor compatibility positively influences RFID adoption intent.	Rejected
Top management support	H5-5: Organizational factor top management support positively influences RFID adoption intent	Rejected
Size	H5-6: Organizational factor organizational size positively influences RFID adoption intent.	Rejected
IT expertise	H5-7: Organizational factor IT expertise positively influences RFID adoption intent	Rejected
Competitive pressure	H5-8: Environmental factor competitive pressure positively influences RFID adoption intent	**Accepted**
External support	H5-9: Environmental factor external support positively influences RFID adoption intent	Rejected
Catalyst agent	H5-10: Environmental factor catalyst agent positively influences RFID adoption intent	**Accepted**
Information intensity	H5-11: Value chain factor information intensity positively influences RFID adoption intent	Rejected
Value chain complexity	H5-12: Value chain factor supply chain complexity positively influences RFID adoption intent	**Accepted**

5.5. Discussion

The purpose of this study is to investigate RFID technology adoption in retail and to examine the effects of technological, organizational, environmental, and value chain variables on the level of RFID adoption. The technological variables that are examined include relative advantage, cost, complexity, and compatibility. The organizational variables that are examined include top management support, organizational size, and IT expertise. The environmental variables that are examined include competitive pressure, external support, and catalyst agent. And finally, the value chain variables that are examined included information intensity and value chain complexity. Multivariate discriminant function analysis (MDA) was used to develop a model for predicting the adoption of RFID in retail.

Results of the analysis indicates that technological variable relative advantage, environmental variables competitive pressure and catalyst agent, and value chain variable value chain complexity are the significant variables to discriminate between the RFID adopters from non-adopters thereby providing strong support for hypotheses 5-1, 5-8, 5-10, and 5-12. Thus, the empirical results indicate that there are significant determinants in each context except the organizational context. This is contrary to what was expected. The results imply that the determinants of RFID adoption in retail should include not only the technological characteristics but also factors related to external environment and the value chain context. Unexpectedly, the same could not be verified for the organizational characteristics. In the next section, each determinant affecting RFID adoption in retail is discussed in detail. The non-significant variables are also discussed in the following section.

5.5.1. Exploring the significant variables

5.5.1.1. Relative advantage

The summary table 5-9 indicates that relative advantage which is a technological characteristic is a significant variable to discriminate RFID adopters from non-adopters as expected. This is consistent with the results of prior studies that have found it to be a significant antecedent for initiating many innovations including RFID (Premkumar and Roberts, 1999; Grover, 1993; Lee and Shim, 2007). Firms adopt technology only if there is a perceived need for it to exploit a business opportunity to gain competitive advantage. Some of the benefits of RFID technology are improved inventory management, improved visibility, improved security from theft and fraud, greater data accuracy, and improved customer service levels (Wamba et al., 2009; Wang et al., 2010; Bhattacharya et al., 2010).

Relative advantage coming out to be a significant antecedent indicates that RFID technology has a high level of relative advantage. This also shows RFID adopters have higher perceived relative advantage levels of RFID as compared to non-adopters. This implies that adopters believe that adopting RFID is beneficial for retailers. This does not however imply that non-adopters think that RFID technology has a low level of relative advantage. As shown in table 5-7, the average perceived relative advantage levels of

RFID for adopters and non-adopters are 4.34 and 3.50 respectively and the 90% lower bounds are 4.25 and 3.38 respectively. The 90% lower bounds are both above 3.0 (neutral assessment) and indicate agreement. However, the lower bound numbers are slightly different. This implies that both adopters and non-adopters believe adopting RFID is beneficial for retailers. However believing that RFID is beneficial is not enough for the non-adopters in deciding whether or not to adopt RFID technology. Other potential constraints or challenges are overshadowing the effects of relative advantage in adoption decisions for non-adopters. The non-adopters are aware of the benefits of RFID technology but did not find any need for these technologies for retail business or they did not know how to situate those benefits in the context of business processes or value chain which is a necessity to reap benefits from the technology. This emphasizes the need to consider an array of factors influencing RFID adoption to get a more detailed understanding and a holistic picture of the adoption scenario.

5.5.1.2. Competitive pressure

The summary table 5-9 indicates that competitive pressure which is an environmental characteristic is a significant variable to discriminate RFID adopters from non-adopters as expected. It is thus an environmental characteristic that stimulates RFID adoption by retailers. This is consistent with the results of previous RFID adoption studies that have found it to be a significant antecedent for initiating RFID adoption (Brown and Russell, 2007; Wamba et al., 2009; Wang et al., 2010). RFID adopters perceive significantly higher competitive pressure for RFID adoption than non-adopters.

Many large retailers mandating their top suppliers to tag their products at pallet or case level is influencing other retailers to jump into RFID adoption to stay in business. It is becoming more of a strategic necessity for other retailers who are still not actively pursuing RFID adoption. When competitor retailers use RFID that provides them competitive advantage, other retailers will feel pressure and be more receptive to RFID. This implies that RFID adopters feel higher perceived competitive pressure as compared to non-adopters. As shown in table 5-7, the average perceived competitive pressure levels for RFID adopters and non-adopters are 3.02 and 2.06 and the 90% lower bounds are 2.84 and 1.89 respectively. Both the lower bound numbers are below 3.0 (neutral assessment) and indicates disagreement in a scale of 1-5. This implies that RFID adopters as well as non- adopters believe that competitive pressure does not drive RFID adoption in retail. However from the discriminant loading in table 5-6 we see that competitive pressure is a significant antecedent for initiating RFID adoption. This indicates that there is some difference in the expert perceptions when it comes to competitive pressure. Also, please note that the adopter 90% lower bound is very close to 3 indicating moderate agreement. This implies that RFID adopters moderately believe that competitive pressure drives RFID adoption in retail whereas non-adopters believe that competitive pressure does not drive RFID adoption in retail. This notion might change with increasing awareness through more situated success cases of RFID adoption in retail.

5.5.1.3. Catalyst agent

The summary table 5-9 indicates that an external catalyst agent which is an environmental characteristic is a significant variable to discriminate RFID adopters from non-adopters as expected. It is thus an environmental stimulator of RFID adoption by retailers. This is consistent with the results of previous RFID adoption studies that have found it to be a significant antecedent for initiating RFID adoption (Brown and Russell, 2007; Wamba et al., 2009; Wang et al., 2010). These catalyst agents are EPC global initiatives for RFID standardization, government influence in the form of mandates such as FDA (Food and drugs administration) and DOD (US department of defense) requirements pushing for case, pallet, or item level RFID tagging, and perceived consumer readiness for RFID tagging of products through increased awareness about the technology. Consistency and interoperability between value chain partners achieved through global RFID standard initiatives can allow firms to leverage cross-industry benefits.

RFID adopters perceive significantly higher levels of external catalyst agents than non-adopters. As shown in table 5-7, the average perceived catalyst agent levels for RFID adopters and non-adopters are 3.25 and 2.75 and the 90% lower bounds are 3.15 and 2.64 respectively. The first lower bound number is above 3.0 (neutral assessment) and indicates agreement in a scale of 1-5 whereas the second lower bound number indicates disagreement. This implies that RFID adopters believe that external catalyst agents drive RFID adoption in retail whereas non-adopters believe that they do not drive adoption.

This implies that influence of external catalyst agent clearly discriminates between the two groups of RFID adopters and non-adopters.

5.5.1.4. Value chain complexity

Value chain complexity which is a value chain characteristic is a significant variable to discriminate RFID adopters from non-adopters. This implies that the more complex is the value chain of operation in terms of dealing with too many value chain partners or uncertainty while doing business, the more likely it is that the retailers will adopt RFID technology. To my best knowledge, the variable of value chain complexity has not been investigated in previous RFID adoption studies. Traditionally, it is assumed that RFID implementation could get very complex and tedious in real world complicated value chain scenario involving multiple relationships. However, from this study it is observed that RFID benefits relative to the cost might be more balanced in a complex value chain situation and thus justifies RFID adoption.

RFID adopters perceive significantly higher levels of value chain complexity as compared to non-adopters. As shown in table 5-7, the average perceived value chain complexity levels for RFID adopters and non-adopters are 3.17 and 2.53 and the 95% lower bounds are 2.98 and 2.35 respectively. The first number is very close to 3.0 (neutral assessment) and indicates agreement in a scale of 1-5 whereas the second number indicates disagreement. This implies that RFID adopters believe that value chain complexity drives RFID adoption in retail whereas non-adopters believe that it does not drive RFID adoption. This implies that influence of value chain complexity discriminates between the two groups of RFID adopters and non-adopters. More empirical research on RFID adoption is needed to further validate the efficacy of the value chain complexity variable.

5.5.2. Exploring the non-significant variables

5.5.2.1. Technological characteristics: Cost, complexity, and compatibility

Technological factors cost, complexity, and compatibility are found not to be significantly determining RFID adoption in retail. High cost issues and complexity of RFID technology are expected to be significant inhibitors of RFID adoption whereas compatibility with previous technologies and current business values and objectives is expected to be positively influencing adoption. However, based on the results of this study, these technological characteristics do not successfully discriminate between RFID adopters and non-adopters. This is contrary to what is observed in previous RFID adoption studies (Brown and Russell, 2007; Wang et al., 2010).

As shown in table 5-7, the average perceived cost for RFID adopters and non-adopters are 2.56 and 2.77 and 90% lower bounds are 2.39 and 2.57 respectively. Similarly, the average perceived complexity for RFID adopters and non- adopters are 2.44 and 2.42 and 90% lower bounds are 2.27 and 2.29 respectively. And finally, the average perceived compatibility for RFID adopters and non-adopters are 2.29 and 2.40 and 95% lower bounds are 2.12 and 2.25 respectively. All these lower bound numbers are below 3.0 (neutral assessment) and indicates disagreement in a scale of 1-5. This implies that RFID adopters as well as non- adopters believe that the technological characteristics cost, complexity, and compatibility do not drive RFID adoption in retail.

This is contrary to what is expected and implies that high cost and complexity are not significant constraints of RFID adoption. It may be that decreasing cost of RFID tags and increasing maturity of RFID technology and services is contributing to these factors being insignificant in RFID adoption decisions. Unexpectedly compatibility factor also came out to be insignificant in this study. This could imply that firms which are starting fresh with RFID technology rather than those which have already invested a huge amount on previous technologies are more likely to adopt it. Firms that already made huge investments on older technologies need to upgrade their existing infrastructures, values, and objectives which might be a huge barrier for them. This also implies that the firms should look beyond the technological constraints to make RFID adoption a success. This study shows that the environmental and value chain characteristics should be emphasized rather than technological characteristics alone while making adoption decisions contrary to popular beliefs.

5.5.2.2. Organizational characteristics: Top management support, organizational size, and IT expertise

Unexpectedly, the organizational characteristics of top management support, organizational size, and IT expertise do not significantly impact RFID adoption in retail. This is consistent with prior RFID adoption studies (Leimeister et al., 2009; Wang et al., 2010). Top management support has been found to be critical in most prior studies on technology adoption (Premkumar et al., 1997). The contrasting result in this study may be due to the presence of more influential environmental characteristics. One possible explanation for the insignificance of top management support for RFID adoption is that most retailers are influenced by factors that are relevant to the external business environment or value chain in which the business operates rather than by the internal decision maker's perspectives. Competitive pressure arising from most big retailers mandating their suppliers and the perceived benefits of RFID providing competitive advantage might be driving RFID adoption more significantly as compared to internal perceptions of top management. Another possible explanation could be relative newness of RFID technology that might contribute to lesser degree of commitment from top management who prefer to rather wait and watch how well RFID technology develops and better learn how to implement it appropriately thus taking fewer risks. Again this implies the need for more empirical investigation of RFID adoption. As shown in table 5-7, the average perceived top management support for RFID adopters and non- adopters are 2.87 and 2.51 and 90% lower bounds are 2.72 and 2.40 respectively. Both the lower bound numbers are below 3.0 (neutral assessment) and indicates disagreement in a scale of 1-5. This implies that RFID adopters as well as non- adopters believe that the organizational characteristic top management support does not drive RFID adoption in retail.

Organizational size also emerged as an insignificant factor influencing RFID adoption. This is contrary to what is expected since it is easier for larger firms to invest on new technologies since they have more slack resources and have greater capabilities to take risks. However, in this study the effect of organizational size is not significant. One possible explanation for this could be that it is simpler for smaller organizations to implement the technology given lesser degree of complexity in their value chain and lower cost of required hardware and software. However, the insignificance does not imply that RFID adopters and non-adopters do not perceive that organizational size is important for RFID adoption. As shown in table 5-7, the average perceived influence of organizational size for RFID adopters and non- adopters are 3.39 and 3.44 and 90% lower bounds are 3.16 and 3.20 respectively. Both the lower bound numbers are above 3.0 (neutral assessment) and indicates agreement in a scale of 1-5. This implies that RFID adopters as well as non- adopters believe that the organizational characteristic top management support is important for RFID adoption in retail. However both do not believe that organizational size significantly determines RFID adoption in retail. Thus, the variable organizational size does not significantly discriminate the adopters from the non-adopters of RFID.

IT expertise also emerged to be insignificant in determining RFID adoption. This implies that existing IT expertise may not be sufficient for successful RFID adoption. A possible explanation for this could be again due to relative immaturity of RFID technology. Even if the firms acquire sufficient IT expertise they are still uncertain about the exact requirements for successful RFID adoption. Also being extremely familiar and used to older technologies might actually raise a potential barrier in adopting a new technology thus creating some resistance. This situation is most likely to change with technological advancements and increasing working knowledge about RFID technology. As shown in table 5-7, the average perceived IT expertise levels of RFID for adopters and non-adopters are 3.89 and 3.54 and 90% lower bounds are 3.77 and 3.41 respectively.

These two lower bound numbers are both above 3.0 (neutral assessment) and indicates agreement. This implies that both adopters and non-adopters believe IT expertise is important for RFID adoption in retail. However, believing that is not enough in making adoption decisions.

As previously discussed in the results section, please note that both top management support and IT expertise were close to the critical cut off value of 0.3 (Structural loading). Thus the alternative explanation for the insignificance could be that the influence of these variables might have been overshadowed due to the presence of other stronger variables and thus these variables must be explored in future research. Given the results of this study, it is hard to make bold claims about these two variables.

5.5.2.3. Environmental characteristic: External support

The environmental characteristic external support is not found to be significant for determining RFID adoption in retail. The evidence about the significance of external support has been diverse in technology adoption studies (Premkumar and Roberts, 1999). (Brown and Russell, 2007) found that external support is crucial and determines RFID adoption. External support is expected to be very important for RFID adoption since very few firms have complete in-house expertise to deal with the wide array of issues associated with RFID implementation followed by maintenance. The only plausible explanation for the insignificance of this variable is that an overwhelming influence of other significant variables on the RFID adoption decision has overshadowed the effect of external support on RFID adoption. For example, the environmental factors of competitive pressure and catalyst agents might be too strong and thus undermine the effect of the external support factor. Or on the other hand, the level of availability of external support from vendors or third party service providers might be same for both adopters and non-adopters. Thus, external support is not a significant variable to discriminate between adopters and non-adopters.

As shown in table 5-7, the average perceived external support levels for adopters and non-adopters are 3.49 and 3.37 and 90% lower bounds are 3.35 and 3.26 respectively. These two lower bound numbers are both above 3.0 (neutral assessment) and indicates agreement. However the numbers are slightly different. This implies that both adopters and non-adopters believe that external support is important for RFID adoption in retail. However believing that external support is important is not enough in deciding whether or not to adopt RFID technology.

From table 5-6, it is also observed that technological characteristic complexity and organizational characteristic IT expertise are not significant. This implies that both adopters and non-adopters of RFID technology perceive it to be a not so complex technology, have sufficient in house IT expertise and thus does not need external support from vendors, third party service providers, or business partners. This is a welcoming trend, if the argument is true. However, a relatively slow RFID adoption rate in retail tells a different story. Thus more research is required to determine the exact reason for this result.

5.5.2.4. Value chain characteristics: Information intensity

The value chain characteristic information intensity also emerged to be insignificant in determining RFID adoption in retail. Previous research on technology adoption has diverse findings when it comes to the effect of information intensity driving adoption. Some studies reported that information intensity positively influences technology adoption whereas others reported that it negatively influences technology adoption. The result from this study is inconsistent with prior RFID adoption study (Wang et al., 2010) who reported that information intensive environment negatively influences RFID adoption. The explanation for the insignificance of information intensity in this study could be due to the presence of other significant factors which overshadowed its effect. Another argument would be that traditional retail environment may not be as information intensive as some other businesses and thus it is not very crucial when it comes to adoption decision. This argument is supported from results in table 5-7 that indicates that the average perceived information intensity levels for adopters and non-adopters are 2.78 and 2.47 and 90% lower bounds are 2.63 and 2.33 respectively. These two lower bound numbers are both below 3.0 (neutral assessment) and indicates disagreement. This implies that both adopters and non-adopters believe that retail value chain is not very information intensive and thus it emerged to be an insignificant factor for determining RFID adoption. Additional research needs to be continued for more concrete conclusions to be drawn about this variable. Figure 5-2 below shows the adoption model result summary.

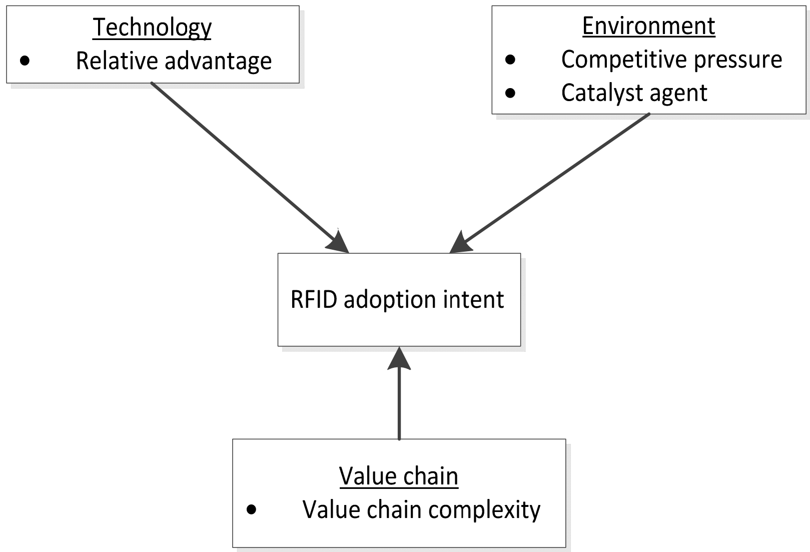


Figure 5-2. RFID adoption model results summary

5.6. Summary

Motivated by the need to understand the underlying antecedents of RFID adoption in retail, this study proposed and tested a framework predicting RFID adoption intent. Based on the TOE framework, this research develops and validates the research framework to examine the influence of twelve contextual factors under four broad categories (technological, organizational, environmental, and value-chain) on RFID adoption in retail. A structured study instrument is developed to measure these variables and data are collected from 74 experts spread across different business associations. Multivariate discriminant analysis (MDA) is used to develop the conceptual framework for RFID adoption. The contributions of this study are multi-fold.

First, the study identifies key determinants of RFID adoption in retail. The key findings are as follows:

1. RFID adoption in retail depends on technological, environmental, and value chain contexts.
2. Four variables (Relative advantage, competitive pressure, catalyst agent, and value chain complexity) are found to be significant determinants of RFID adoption in retail.
3. All four variables are successful facilitators of RFID adoption in retail.
4. Environmental characteristics are very important to be considered in RFID adoption studies along with technological and value chain characteristics.
5. Organizational characteristics top management support and IT expertise are close to being significant, however their effects are overshadowed in the presence of much stronger environmental characteristics that influence RFID adoption. This could explain slower RFID adoption rate than originally expected. Thus, no arguments could be made for organizational characteristics influencing RFID adoption in this study which is in sharp contrast with other RFID adoption studies.

Secondly, this study verifies the applicability of TOE framework for RFID adoption studies and extends the framework by adding another dimension of value chain context to it that makes it more suitable for RFID research since the technology is primarily used to streamline value chain activities.

Third, this study finds two significant facilitators of RFID adoption (Catalyst agent and value chain complexity) which are rarely investigated in previous RFID adoption studies.

Fourth, compared to previous research, this study uses a large and diverse pool of experts to develop the conceptual framework of RFID adoption. Thus, the findings are valuable and could act as an impetus for future research on many issues. For example, a longitudinal study could be conducted to investigate the influence of these variables across different levels of adoption through diffusion and use. The applicability of the adoption framework could also be investigated for other industries or other automatic-identification technologies in general.

Chapter 6

Conclusions and Contributions

This chapter provides the reader with a summary of the key findings of this dissertation work. It also discusses overall contributions of this dissertation followed by limitations and future research directions that are envisioned.

6.1. Key findings

This dissertation dealt with the following research questions:

1. **What is the impact of RFID on retail value chain?**

To answer this questions a conceptual framework of the impact of RFID is derived in this dissertation. As a first step, a comprehensive content analysis of the topic is performed and key themes or issues that are important to be investigated are identified to understand the impact of RFID on retail value chain. These issues include current RFID adoption status, potential benefits, RFID applicable business processes and value chain activities, challenges, technological choices, and diffusion strategy along with adoption drivers. The conceptual framework is developed based on content analysis results combined with Delphi study results under the light of the theory of diffusion of innovations (DOI) and the theory of business value of IT. The framework situates the key research issues across different adoption stages. It thus puts those issues into a theoretical perspective. Additionally the most significant of each of these issues are identified and discussed. The integrated conceptual framework of the impact of RFID distinguishes between different stages in adoption process and associates key adoption issues with each stage. The framework verifies that these issues should be studied using an integrated approach rather than being investigated as separate issues. Retailers could make improved business decisions about adopting RFID based on the results of the derived conceptual framework.

2. What are the determinants of retail adoption of RFID technology?

To answer this question, a conceptual framework of RFID adoption in retail is derived in this dissertation based on Delphi study results. The conceptual framework is developed under the light of TOE (technology-organizational-environment) framework. This framework could be adapted for other industries or other automatic identification technologies in general.

A research framework is developed and validated to investigate the influence of twelve contextual factors under four broad categories (technological, organizational, environmental, and value-chain) on RFID adoption in retail.

Four variables (Relative advantage, competitive pressure, catalyst agent, and value chain complexity) are found to be significant facilitators of RFID adoption in retail. Environmental characteristics emerged to be very important to be considered in RFID adoption studies along with technological and value chain characteristics.

6.2. Contributions

The contributions of this dissertation research work are separated into industrial, theoretical, and methodological. The majority of the contribution is industrial or management oriented since this dissertation research is applied in nature. However the theoretical and methodological contributions are also significant.

An industrial contribution of this research is the identification followed by detailed description of key issues pertaining to the impact of RFID technology on retail value chain that will provide decision makers with adequate comprehensive knowledge for making RFID technology adoption decisions. This research work will fulfill practitioner's needs to understand the impact of RFID on value chains particularly for retailers. The derived conceptual framework of the impact of RFID has sought to improve the practical understanding of key issues such as potential benefits, RFID applicable business processes and value chain activities, and challenges. The conceptual framework of RFID adoption improves practical understanding of driving forces influencing RFID adoption in retail.

The theoretical contribution of this dissertation research lies in three areas:

1. First, a theoretical framework that conceptualizes the impact of RFID on retail value chain is derived. So far, RFID research lacks a theoretical foundation. The derived framework links the research on RFID to existing research in the areas of diffusion of innovations and business value of information technology (IT).

2. Second, a theoretical framework conceptualizing RFID adoption in retail is developed. Key antecedents driving RFID adoption in retail are identified and discussed.
3. This dissertation research empirically verifies and supports the applicability of the theories of ‘Rogers diffusion of innovation’, ‘Business value of IT, and ‘TOE framework’ in understanding RFID adoption. These theories are adapted and extended to make them more relevant to the field of RFID research.

The derived frameworks can be used as platforms for future research work in the field of RFID adoption or as a matter of fact for any other automatic-identification technology in general. The frameworks take holistic views toward all relevant issues and are thus comprehensive.

The methodological contribution of this dissertation is that it shows that the research methods of content analysis and Delphi method could be used in a complementary fashion thus allowing the researcher to gain synergies, harmonize the weaknesses and assess the relative strengths of each individual method. Adopting two methodological perspectives provides an extended view of the phenomenon under investigation. The dissertation research also shows the applicability of these research methods specifically for RFID adoption research.

6.3. Limitations

Limitations exist in this research work with respect to the epistemological position and proposed methodologies as with any other study. One limitation of conducting explorative and inductive research is that when the researcher has analyzed the empirical data, she / he might identify an issue, problem, or phenomenon that would have been more interesting to investigate. This may lead to either ignoring the issue for future research or re-analyzing the data with respect to the new issue of interest.

The specific disadvantages for using sequential mixed research design include (Creswell, 2002; Green and Caracelli, 1997):

1. As any mixed methods design, it requires lengthy time to complete.
2. It requires feasibility of resources to collect and analyze both types of data.

In terms of methodological limitations, the researcher could be viewed as biased because of prior knowledge and pre-convictions that could influence the data coding process that further impacts the whole research process. Thus, the researcher must account for detailed exact process followed while conducting data collection through theme identification and data analysis. However several iterations of the coding process along with computer aided content analysis of part of the data set add to the reliability of the coding process in this research work. The other limitation comes from the choice of experts for the Delphi study. The choice could also be viewed as biased and unrepresentative of the overall sample. To account researcher bias as well as to reduce inherent bias within a particular sector having similar backgrounds was attempted to be reduced, by selecting candidates from different business associations such as consulting, academia, retail, and third party service providers.

Sample size of the number of documents analyzed for content analysis and the number of experts included in the Delphi study are limited based on availability and also due to time constraints. The number of experts within each business association is not exactly same. It introduces some additional risk of bias inherent in a particular sector still remaining.

There is a risk of drawing false conclusions from the results of the research because full scale implementations have not taken place in most firms. The content analysis dataset primarily consists of industry pilot study results and those results directly influenced the Delphi study. Experts participating in the Delphi study have also expressed their perceptions based on limited exposure that lacks full scale RFID implementation experience. Finally, the research findings may not necessarily be generalizable to other industries. These limitations represent areas for future research in order to further bolster and generalize the findings.

6.4. Future research

Even if this dissertation has explored RFID adoption issues, thereby contributing to RFID research and practice, there are several areas which would be interesting to explore further. First, it must be stated that this research only focuses on the retail end of the value chain and thus by no means provides a complete description of the interaction of all entities in the retail value chain.

The impact of RFID on entities other than retail end of the value chain has not been considered. For future research, the impact of RFID on other entities across the value chain like manufacturing, distribution, and consumers is envisioned. This could provide further deeper insights thus contributing to a wide-spread RFID adoption across different sectors.

Conducting in-depth separate case studies across different entities of the retail value chain will shed more light on existing inefficient activities along the value chain and also on more efficient activities that could be made possible using RFID technology. Multiple case studies across the retail value chain will also allow performing comparative analysis of the impact of RFID spread across different entities of the value chain.

Additionally, the conceptual frameworks of the impact and adoption of RFID should be further investigated for different value chain entities using more rigorous methodologies. For example, significance of the models could be further validated and extended by considering smaller models, multiple participants within each organization, and complementing of questionnaire techniques with follow up interviews. Examining specific industry wide differences in use of RFID technology and adoption process will be an interesting topic to study.

A longitudinal study of both the impact and adoption of RFID for retail and other entities of the value chain would be extremely insightful for revealing the dynamics of the adoption process. Given that external environmental conditions contribute to fast technology adoption decisions, future research could explore different phases of RFID adoption from initiating through diffusion and use and identify which factors are more relevant and thus influence specific phase of adoption.

The inter-relationship among the independent variables specifically in the RFID adoption framework could be investigated in future research. Such inter-relationships were beyond the scope of this study. Many other variables in the TOE framework, such as privacy and security concerns may be potential determinants of RFID adoption. Future research may incorporate new and relevant variables into the research framework for an improved understanding. Thus in a nutshell, the framework needs to be generalized to other contexts to allow for new predictions, by conducting more empirical studies.

Finally, for future research, RFID adoption could be contrasted to the diffusion of other complex organizational IT systems such as EDI or ERP. Also, a cross-country comparative analysis of RFID adoption analyzing the role of different cultural backgrounds of decision makers and employees and different corporate cultures will be interesting to pursue.

6.5. Recommendations

This dissertation offers four recommendations to firms that want to determine their approach to RFID adoption:

1. **Situate RFID benefits in the context of business processes and value chain activities:** The conceptual framework of the impact of RFID suggests that firms should take a holistic approach when considering RFID

adoption. Focusing just on direct potential RFID benefits could lead to a lot of uncertainty being generated during later phases of adoption. Situating the benefits in a particular context will allow potential adopters to identify the most important aspects that they can and want to improve using RFID. Thus, a firm specific adoption approach should be taken to avoid potential problems that may come up later on.

2. **Focus on informational and transformational effects of RFID:** There is a tendency of most early adopters to only focus on the automational effect of RFID technology which only streamlines manual rote tasks. However the real potential of RFID is utilized when firms look for new and innovative ways to use the technology to achieve informational and transformational effects of the technology. The conceptual impact framework suggests that investment in RFID technology will make sense only when firms will look out for these unique aspects of the technology.

3. **Do not ignore indirect benefits of RFID:** The conceptual impact framework suggests that there are many indirect benefits of RFID along with the direct benefits. For example, improved customer services is an indirect benefits of RFID that results from more direct benefit such as reduced out of stock. Similarly, improved collaboration is an indirect benefit that could result from more direct benefit of improved data accuracy. Thus firms must consider the indirect benefits of RFID along

with more tangible direct benefits while assessing RFID technology and take a long term approach since indirect benefits are hard to measure and have a longer pay-back period.

4. **Consider environmental and value chain characteristics along with technological characteristics while making RFID adoption decisions:** The conceptual framework of RFID adoption suggests that firms must consider environmental and value chain characteristics rather than just focusing on the technological characteristics while making RFID adoption decisions. RFID adoption might be more sensible when all these characteristics are taken into consideration. This will allow decision makers to make a more informed and thus correct decision.

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Appendix A

Delphi Study Instrument

Your participation in this Delphi study is vital to understanding the impact of RFID on Retail sector. We are investigating key adoption issues specifically for retail such as adoption drivers, benefits, business processes, value chain activities, challenges, and major trends in this research. A summary of the results will be made available to everyone who completes the questionnaire giving you an opportunity to change your opinions if you choose to. Finally a complete research report with detailed comparative analysis between content analysis and Delphi study results will be made available to everyone who participates in this study as an acknowledgment for their valuable inputs and time. Please take a moment to take this online survey which should take no longer than 15-20 minutes. Below is our consent form. Completion of the survey implies that you have read the information in this form and consent to take part in the research.

Implied Informed Consent Form for Social Science Research

The Pennsylvania State University

Title of Project: Exploratory Study of Impact of RFID on Retail Sector

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1. **Purpose of the Study:** The purpose of this research study is to explore how Radio Frequency Identification (RFID) technology impacts retail sector. Also of interest is to understand key RFID adoption issues in retail sector.
2. **Procedures to be followed:** You will be asked to participate in a Delphi study. You will be required to answer 33 questions on a survey. The combined results will be sent to you giving you an opportunity to change your opinions if you wish to.
3. **Duration:** It will take about 15-20 minutes to complete the survey. If you wish to change your opinions during the second round you may do so within 5-10 minutes.
4. **Statement of Confidentiality:** Your participation in this research is confidential. No one other than investigators will have access to your responses. Your data will be stored with a participant number, not a personal identifier such as a name. All presentations of this research will report your data using this anonymous code; in most cases your data will appear only as part of a group summary. Your name will not appear in professional presentations or publications. All data will be stored in a password protected computer. Only the principal investigator will have access to the password protected computer. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, Penn State University's Social Science Institutional

Review Board and Penn State University's Office for Research Protections. Your confidentiality will be kept to the degree permitted by the technology used. No guarantees can be made regarding the interception of data sent via the internet by any third parties.

5. **Right to Ask Questions:** Please contact Mithu Bhattacharya (814) 321-5444 with questions or concerns about this study.
6. **Voluntary Participation:** Your decision to be in this research is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer.

You must be 18 years of age or older to take part in this research study.

Completion and return of the survey implies that you have read the information in this form and consent to take part in the research. Please keep this form for your records for future reference.

This informed consent form was reviewed and approved by the Office for Research Protections (IRB#32286) at The Pennsylvania State University on (11-24-2009). It will expire on (11-24-2012).

1. Do you consent to take part in this research?

- I agree
- I do not agree

2. Participant Information

1. Please select the item that best describes your field of business association.

- Academia
- Consulting
- Third party service providers

- Retail
- Other (Please specify)

2. Please indicate what best describes your position.

- Top management
- IT management
- Executive staff
- Research
- Other (Please specify)

3. Are you familiar with RFID (Radio Frequency Identification) and its uses?

- I know all about RFID
- I have good knowledge about RFID
- I have some knowledge of what it is
- I have only heard about it
- I am not familiar with it at all
- Other (Please specify)

4. How long have you been involved with RFID projects?

- 6 months - 1 year
- 1 - 3 years
- 3 - 5 years
- Greater than 5 years

5. Your email address. Please note that email address will be used for the purpose of acknowledgement and to provide summary results of the questionnaire only. All email/surveys will be treated in confidence.

____

3. Impact of RFID

Instructions: Please think about consumer products like grocery, fresh produce and sea food, dvds and games, furniture, tableware, accessories (jewellery, watches, eye wear etc.), health and beauty products, alcohol and cigarettes, electronics etc. that could be tagged by RFID when you express your opinions. Based on your individual perception along with industry or professional experience please answer the following questions.

The statements are scaled from 1 to 5, with 1 being 'strongly disagree' and 5 being 'strongly agree'. Read each statement carefully, then using the following scale, decide the extent to which it actually applies to you. Attempt all statements.

Strongly disagree = 1

Disagree = 2

More-or-less agree = 3

Agree = 4

Strongly agree = 5

6. What are the major benefits from RFID adoption in Retail sector?

- Reduced out of stock
- Reduced inventory
- Reduced missing sales
- Reduced shrinkage
- Improved data accuracy (inventory, shipping etc.)
- Business intelligence
- Improved collaboration with business partners
- Real-time visibility
- Improved visibility of orders and inventory
- Improved asset management
- Tracking shopping behavior

- Tracking temperature for food products
- Monitor worker productivity
- Improved customer service levels
- Increased sales
- Accuracy, speed, and efficiency of processes
- Improved returns/recall management
- Improved labor productivity
- Reduced overall cost of operations
- Reduced labor costs
- Competitive advantage
- Improved security against theft/fraud/counterfeiting
- Other comments (Please specify)

7. What retail business processes could be improved by RFID adoption?

- Tracking and tracing
- Replenishing
- Receiving
- Checkout
- Demand forecasting
- Re-use and recycle/Returns
- Shipping
- Picking
- Ordering
- Transport
- Storing
- Other comments (Please specify)

8. What retail value chain activities could be improved by RFID adoption?

- Replenish, allocation, and scheduling (involves managing resources to avoid out of stock situations)
- Warehouse management and distribution (involves managing diverse warehouse facilities to achieve improved distribution)
- In-store operations (involves management of various store operations, such as receiving, shelf stocking, and product ordering for store replenishment)
- Sales planning (involves planning routes and distribution channels to reach target customers)
- Sales (involves revenue generation)

- Returns/ Recall (involves managing return merchandise)
- Promotion planning (involves planning and managing promotions)
- Merchandise planning (involves planning and maintaining a balance between sales and inventory)
- Price management (involves understanding, managing, and improving pricing decisions based on forecast data)
- Assortment planning (involves planning and proper selection of merchandise to meet a variety of customer needs)
- Other comments (Please specify)

9. What are the major challenges for RFID adoption in retail?

- Privacy issues
- High cost
- Technical limitations
- Data warehousing and integration
- Lack of standards
- Business process redesign
- Unclear return on investment (ROI)
- Multiple frequencies
- Resistance to change (by workers or management)
- Lack of top management support
- Lack of technical expertise
- Complexity of the technology
- Other comments (Please specify)

3. Adoption Trends

10. Please rate how important each of the following frequencies are for retail sector?

- Ultra high frequency (UHF)
- High frequency (HF)
- Near field UHF
- Low frequency
- Other comments (Please specify)

11. What kinds of tags are used by retail sector?

- Passive tags
- Active tags
- Passive dual frequency tags
- Other comments (Please specify)

12. What tagging levels are appealing to the retail sector?

- Pallet
- Case
- Item
- Other comments (Please specify)

13. What is your opinion about the current RFID adoption status in retail?

- Complying with trading partner requests or government mandates
- Improved efficiencies of specific current processes within the organization
- New processes and applications are coming up due to RFID capabilities

14. What is your opinion about the dimensions of business value of RFID in retail?

- Enhance efficiency by substituting capital for labor
- Enhance performance through improved capabilities to collect, store, process, and disseminate information leading to better decisions and quality
- Facilitating process reengineering and redesigning organizational structures across value chain
- Other comments (Please specify)

15. What is the RFID diffusion strategy in retail?

- Top administrative management perceptions, decisions, and strategies drive adoption and diffusion
- Impetus for RFID innovation grows from individual users of the technology
- Other comments (Please specify)

4. Technological Adoption factors

16. Does relative advantage influence RFID adoption in retail? How true is each of this statement?

- RFID allows for improved inventory management
- RFID provides better information accuracy for better decision making and collaboration
- RFID provides improved visibility
- RFID allows for improved customer service levels and sales
- RFID provides improved operational efficiency
- RFID provides improved security against theft and counterfeiting
- Other Comments (Please specify)

17. Does cost influence RFID adoption in retail? How true is each of this statement?

- The costs of adopting RFID technology are far greater than the benefits
- The cost of maintenance and support of RFID technology is very high
- The amount of money and time invested in training employees to use RFID technology is very high
- Other Comments (Please specify)

18. Does complexity influence RFID adoption in retail? How true is each of this statement?

- The skills required to use RFID technology are too complex for employees
- Integrating RFID technology in current retail work practices is very difficult
- Integrating RFID systems with existing IT systems is very complex
- Massive amounts of data generated by RFID is very difficult to manage
- Other Comments (Please specify)

19. Does compatibility influence RFID adoption in retail? How true is each of this statement?

- Implementing the changes caused by RFID adoption is not compatible with most retailer business approaches and objectives
- RFID is not compatible with retailer's experience with similar auto-ID technology
- Other Comments (Please specify)

5. Organizational Adoption Factors

20. Does top management support influence RFID adoption in retail? How true is each of this statement?

- Top management enthusiastically supports the adoption of RFID technology
- Top management allocates adequate resources to adoption of RFID technology
- Top management is aware of the benefits from RFID
- Top management actively encourages employees to use RFID technology in their daily tasks
- Other Comments (Please specify)

21. Does organizational size influence RFID adoption in retail?

- Organization size positively influences RFID adoption in retail
- Other Comments (Please specify)

22. Does existing IT expertise influence RFID adoption in retail? How true is each of this statement?

- Greater IT expertise in an organization positively influences RFID adoption in retail
- Greater strategic IT planning positively influences RFID adoption in retail
- Most retailers have a sophisticated database and telecommunication facility
- Other Comments (Please specify)

6. Environmental Adoption Factors

23. Does competitive pressure influence RFID adoption in retail? How true is each of this statement?

- Retailers will lose customers to competitors if they do not adopt RFID technology
- It is a strategic necessity to use RFID to compete in marketplace
- Other Comments (Please specify)

24. Does external support influence RFID adoption in retail? How true is each of this statement?

- There are third party service providers that provide technical support for effective use of RFID technology
- There are agencies who provide training on RFID technology
- Technology vendors actively market RFID technology by providing incentives for adoption
- Technology vendors promote RFID technology by offering free training sessions
- Other Comments (Please specify)

25. Do catalyst agents influence RFID adoption in retail? How true is each of this statement?

- Vendors are trying very hard to sell RFID technology to retailers
- Government is promoting RFID adoption by retailers through specific mandates
- EPC global initiative for standardization is promoting RFID adoption in retail
- Perceived consumer readiness for RFID technology is positively influencing RFID adoption in retail
- Other Comments (Please specify)

7. Value Chain Adoption Factors

26. Does information intensity of retail value chain influence RFID adoption? How true is each of this statement?

- The product/service in retail generally requires a lot of information to sell
- The product/service in retail is complicated or complex to understand
- The ordering of product/service in retail is generally a complex process
- The products in retail industry are characterized by a long cycle time from order to delivered product
- Other Comments (Please specify)

27. Does complexity in retail value chain influence RFID adoption? How true is each of this statement?

- Typically retailers deal with too many value chain partners for doing business
- Typically retailers deal with a lot of uncertainty while doing business with value chain partners
- Other Comments (Please specify)

8. Adoption Intent

28. In the light of technological, organizational, environmental, and value chain factors influencing RFID adoption, please express your opinion about retailers' RFID technology adoption intent.

- Most retailers would intend to adopt RFID technology

9. Diffusion Model

29. Please express your opinion about knowledge phase of RFID diffusion model in retail sector.

- Information about technical aspects of RFID helps retailers to become aware and develop ideas about how it functions
- Information about general RFID adoption status helps retailers to become aware and develop ideas about the technology and its general possibilities
- Other Comments (Please specify)

30. Please express your opinion about persuasion phase of RFID diffusion model in retail sector.

- Information about key RFID adoption drivers influence retailers' favorable or unfavorable attitude toward the technology
- Information about key RFID benefits influence retailers' favorable or unfavorable attitude toward the technology

- Other Comments (Please specify)

31. Please express your opinion about design phase of RFID diffusion model in retail sector.

    - Information about key RFID applicable business processes influence retailers' choice to adopt or reject the technology
    - Information about key RFID applicable value chain activities influence retailers' choice to adopt or reject the technology
    - Information about key choice of technology (frequency, tagging level, and tag types) influence retailers' choice to adopt or reject the technology
    - Other Comments (Please specify)

32. Please express your opinion about implementation phase of RFID diffusion model in retail sector.

    - Information about adoption challenges can improve overall RFID technology implementation process in retail
    - Information about diffusion strategy can improve overall RFID technology implementation process
    - Other Comments (Please specify)

33. **Any additional comments?**

Thank you for participating in this research. We will send you the compiled results giving you an option to change your opinion if you choose to. Finally we will send you the finished research report comprising a detailed analysis between of the findings from the results at the end of the study.

Please submit to complete.

Appendix B

Step-Wise Multivariate Discriminant Analysis Results for RFID Adoption Model

Discriminant

Tests of Equality of Group Means

	Wilk's Lambda	F	df1	df2	Sig.
Relative Advantage	.830	11.636	1	57	.001
cost	.990	.603	1	57	.441
complexity	1.000	.004	1	57	.952
compatibility	.996	.213	1	57	.646
Top management support	.929	4.365	1	57	.041
IT Expertise	.976	1.388	1	57	.244
Competitive pressure	.850	10.095	1	57	.002
External support	.974	1.529	1	57	.221
Catalyst agent	.884	7.490	1	57	.008
Information intensity	.978	1.295	1	57	.260
Value chain complexity	.879	7.838	1	57	.007
Organization size	1.000	.015	1	57	.903

Pooled Within-Groups Matrices

		RA	C	CX	CM	TS	IE	CP	ES	CA	II	VC	S
Correlation	Relative Advantage	1.000	-.373	-.161	-.206	-.014	.104	.044	.213	.059	.109	.264	.062
	cost	-.373	1.000	.540	.514	.293	.177	-.199	-.192	.058	.050	-.053	-.128
	complexity 2	-.161	.540	1.000	.657	.278	.235	-.033	-.142	.216	.366	.032	.151
	compatibility	-.206	.514	.657	1.000	.249	.167	-.233	-.008	.296	.195	.083	-.023
	Top management support	-.014	.293	.278	.249	1.000	.137	-.212	-.069	.157	-.021	.058	.147
	IT Expertise	.104	.177	.235	.167	.137	1.000	-.003	.213	.126	.295	.270	.277
	Competitive pressure	.044	-.199	-.033	-.233	-.212	-.003	1.000	.156	.323	.286	.278	.145
	External support	.213	-.192	-.142	-.008	-.069	.213	.156	1.000	.080	.121	.130	-.071
	Catalyst agent	.059	.058	.216	.296	.157	.126	.323	.080	1.000	.297	.278	.050
	Information intensity	.109	.050	.366	.195	-.021	.295	.286	.121	.297	1.000	.438	.362
	Value chain complexity	.264	-.053	.032	.083	.058	.270	.278	.130	.278	.438	1.000	.298
	Organization size	.062	-.128	.151	-.023	.147	.277	.145	-.071	.050	.362	.298	1.000

Analysis 1

Box's Test of Equality of Covariance Matrices

Log Determinants

Retailers RFID adoption intent - Compressed 2	Rank	Log Determinant
Disagree	3	-1.614
Agree	3	-1.919
Pooled within-groups	3	-1.749

The ranks and natural logarithms of determinants printed are those of the group covariance matrices.

Test Results

Box's M		5.101
F	Approx.	.782
	df1	6
	df2	5010.436
	Sig.	**.584**

Tests null hypothesis of equal population covariance matrices.

Stepwise Statistics

Variables Entered/Removed[a,b,c,d]

		Wilk's Lambda							
						Exact F			
Step	Entered	Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	Relative Advantage	.830	1	1	57.000	11.636	1	57.000	.001
2	Competitive pressure	.733	2	1	57.000	10.223	2	56.000	.000
3	Organizational readiness	.664	3	1	57.000	9.295	3	55.000	.000

At each step, the variable that minimizes the overall Wilk's Lambda is entered.

a. Maximum number of steps is 24.

b. Minimum partial F to enter is 3.84.

c. Maximum partial F to remove is 2.71.

d. F level, tolerance, or VIN insufficient for further computation.

Variables in the Analysis

Step		Tolerance	F to Remove	Wilk's Lambda
1	Relative Advantage Total	1.000	11.636	
2	Relative Advantage Total	.998	8.944	.850
	Competitive pressure total	.998	7.485	.830
3	Relative Advantage Total	.998	7.919	.759
	Competitive pressure total	.953	9.533	.779
	Organizational readiness total	.955	5.717	.733

Wilk's Lambda

						Exact F			
Step	Number of Variables	Lambda	df1	df2	df3	Statistic	df1	df2	Sig.
1	1	.830	1	1	57	11.636	1	57.000	**.001**
2	2	.733	2	1	57	10.223	2	56.000	**.000**
3	3	.664	3	1	57	9.295	3	55.000	**.000**

Summary of Canonical Discriminant Functions

Eigen-values

Function	Eigen-value	% of Variance	Cumulative %	Canonical Correlation
1	.507[a]	100.0	100.0	**.580**

a. First 1 canonical discriminant functions were used in the analysis.

Wilk's Lambda

Test of Function(s)	Wilk's Lambda	Chi-square	df	Sig.
1	.664	22.762	3	**.000**

Standardized Canonical Discriminant Function Coefficients

	Function
	1
Relative Advantage	.612
Top management support	.541
Competitive pressure	.679

Structure Matrix

	Function
	1
Relative Advantage	**.635**
Competitive pressure	**.591**
Top management support	**.389**
Value chain complexity [a]	**.382**
Catalyst agent [a]	**.340**
Information intensity [a]	.249
Organization size [a]	.216
cost [a]	-.205
External support [a]	.199
compatibility [a]	-.150
IT Expertise [a]	.136
complexity [a]	.030

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.

a. This variable not used in the analysis.

Classification Statistics

Classification Results[b,c]

			Predicted Group Membership		
		Retailers RFID Adoption Intent	Disagree	Agree	Total
Original	Count	Disagree	8	11	19
		Agree	3	44	47
		Ungrouped cases	0	1	1
	%	Disagree	42.1	57.9	100.0
		Agree	6.4	93.6	100.0
		Ungrouped cases	.0	100.0	100.0
Cross-validated[a]	Count	Disagree	7	12	19
		Agree	3	44	47
	%	Disagree	36.8	63.2	100.0
		Agree	6.4	93.6	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 78.8% of original grouped cases correctly classified.

c. 77.3% of cross-validated grouped cases correctly classified.

VITA

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EDUCATION

PhD in Information Sciences and Technology (Minor in Statistics) [May, 2011]
College of Information Sciences and Technology
The Pennsylvania State University, University Park, PA, USA

MS in Information Technology (2001-2003)
Birla Institute of Technology, Mesra, Ranchi, India

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RESEARCH INTERESTS

My broad research interests include new technology/innovation adoption, human-computer interaction (HCI), organizational informatics, content analysis, supply chain management, experiment design, and data analysis. My specific interest is on RFID adoption especially on applying relevant diffusion theories to gain a better understanding of the adoption decision making, advance the theoretical framework, and have practical impact. I focus on both the theoretical and empirical aspects of how decision makers make technology adoption decision.

SELECTED PUBLICATIONS

1. Bhattacharya, M., Petrick, I., and Mullen, T. (2010). A delphi study of RFID adoption for business process and value chain optimization. *41st Annual Meeting of Decision Sciences Institute.* (Forthcoming)
2. Bhattacharya, M., Chu, C.H., Mullen, T., & Hayya, J. (2010). An exploratory study of RFID adoption in the retail sector. *Operations Management Research, 3*(1-2), 80-89.
3. Bhattacharya, M., Chu, C.H., & Mullen, T. (2008). A comparative analysis of RFID adoption in retail and manufacturing sectors. *Proceedings of 2ND Annual IEEE Conference on RFID*, Las Vegas, NV, 241-249.